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BIOLOGICAL ASSESSMENT OF DIESEL SPILL
IN THE VICINITY OF ANACORTES, WASHINGTON,
MAY 1971

J. A. Watson, et al

Texas Instruments, Incorporated

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13. ABSTRACT

A survey to assess the biological damage resulting from the 26 April 1971 diesel spill at Anacortes, Washington, was conducted between 9 May and 12 May 1971. A total of 18 traverses was occupied on Guemes, Huckleberry, Saddlebag, Hat, Orcas, and Lummi Islands and Padilla Bay. Analyses of samples of hydrocarbon content using gas chromatography clearly indicate diesel contamination of sediments and water in the high-impact areas. The evidences for environmental damage are both visual (oozing of oil from intertidal sediments) as revealed by photographs and verbal documentation and circumstantial as revealed by the detailed analysis of the faunal data collected during this study. Several common intertidal invertebrates (chitons, large limpets, large and small pelecypods, and large gastropods) and one fish (the common stickleback) were completely absent from the high-impact areas, although they were often collected or observed in 1958 and 1966 in the same region and locally reported to be common before the spill. The control area on Orcas Island was the richest of all regions sampled. Diversity indices illustrated that the lowest diversities were obtained from the areas of largest visible amounts of oil.

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MAY 1971
FINAL REPORT

Prepared for
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Prepared by
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FOREWORD

This final report under Contract 68-01-0017 with the Environmental Protection Agency discusses Texas Instruments assessment of the biological damage resulting from a diesel spill at Anacortes, Washington, in April 1971. Provided (with appropriate interpretations) are a technical evaluation of data; final tables, charts, graphs, and photographs; a data summary; and final conclusions. Also included are a literature review of the tides and tidal-current regime in the vicinity of the spill, appropriate chemical analysis, data on damage to the biological communities as a result of the spill, and data from the spill site collected by scientists at Western Washington State College.

Texas Instruments subcontractor in the collection and analysis of the biological data was Coastal Ecosystems Management, Inc.



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SECTION I

INTRODUCTION

Texas Instruments Incorporated, under Contract 68-01-0017 with the Environmental Protection Agency, conducted a survey to assess the biological damage resulting from a diesel spill at Anacortes, Washington (Figure I-1). The objectives were to gather information on

- Damage to the biological communities as a result of the spill
- Chemical analyses of water, sediments, and biological specimens for hydrocarbon content
- Literature review of the tides and tidal-current regime in the vicinity of the spill

The survey was performed under an EPA Basic Ordering Agreement providing for quick-response environmental surveys to determine sources, causes, and effects of movement or dispersion of oil and hazardous substances spilled in the inland navigable rivers and coastal and estuarine zones. The request called for a biological survey and subsequent analysis as well as a chemical analysis for hydrocarbon content of water, sediment, and biological specimen.

A. BACKGROUND

A United Transportation Company barge began loading No. 2 diesel at the Texaco refinery pier, March Point, Anacortes, Washington, at 1800 hr on 25 April 1971. At 0230 hr on 26 April, it was discovered that a valve aboard the vessel had been left open and that a spill had occurred. The initial estimate of the spill was 5000 gal — a figure that would subsequently become 5000 bbl (260,000 gal).

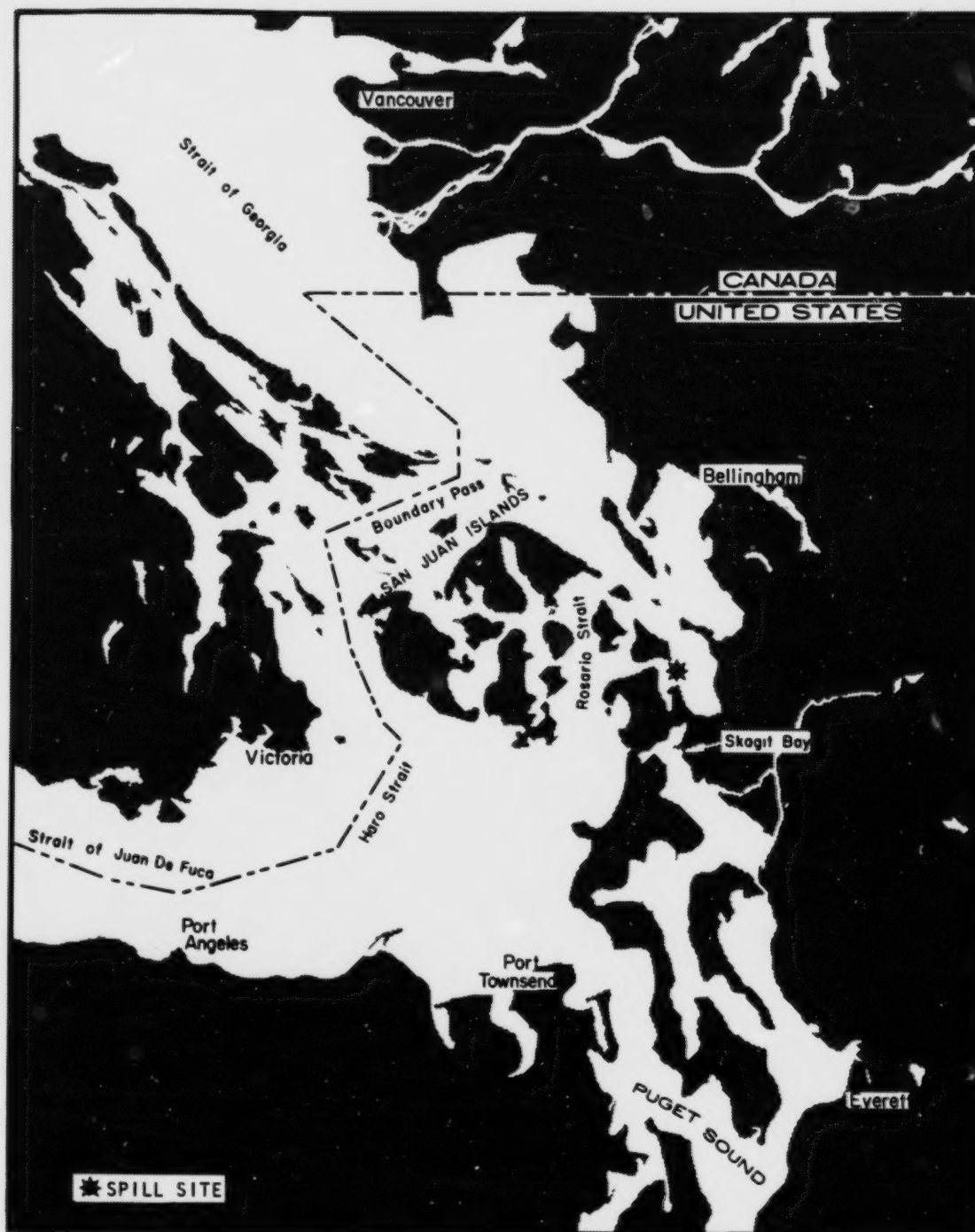


Figure I-1. San Juan Island Region



Immediate visible signs of damage to the biologic community was the loss of approximately 350 waterfowl along the south shore of Guemes Island and the north shore of Fidalgo Island at Anacortes. Aerial surveillance of the diesel slick by EPA and state personnel later in the week indicated slick movement out of Rosario Strait into the Strait of Juan de Fuca.

On 3 May 1971, Texas Instruments was issued a preliminary work statement by EPA to conduct a technical field survey and investigation of a diesel fuel spill. TI subcontracted with Coastal Ecosystems Management, Inc. (CEM) for the biological portion of the survey. The detailed work statement, as approved by EPA, included data collection, analysis, and interpretation of

- Six transects along the south shore of Guemes Island
- One transect each on Huckleberry, Saddlebag, and Hat Islands
- Three transects at Deer Point on Orcas Island (this, to be a control area)
- One transect 0.5 mi south of March Point in Padilla Bay
- Three stations in Padilla Bay
- Two transects on Lummi Island

A series of stations along each transect were described biologically and samples taken for detailed biological and chemical analyses in the laboratory. Section II describes field techniques and data analyses and interpretation.

B. OPERATIONS

A Texas Instruments team was activated 3 May 1971 to respond with a preliminary study plan for a survey of the spill area. TI and CEM personnel met with regional EPA personnel on 4 May 1971 and developed a detailed approach.



In conjunction with EPA, a detailed study plan was assembled and the field crew and equipment left Dallas, Texas, on 7 May 1971. A reconnaissance survey of the spill area was made on 8 May 1971 aboard the R/V OCEANITE, a 34-ft fiberglass work boat. Field data collection extended from 9 May to 12 May 1971.

Figure I-2 and Table I-1 indicate locations of the shore traverses and stations. Shore traverses were located perpendicular to the shoreline and extended from high tide to the subtidal zone. Most shore traverses contain five sampling stations. At each station, the epifauna were described and a series of samples including epifauna, infauna, bacteriological, sedimentological, and water and sediment taken for hydrocarbon analysis.

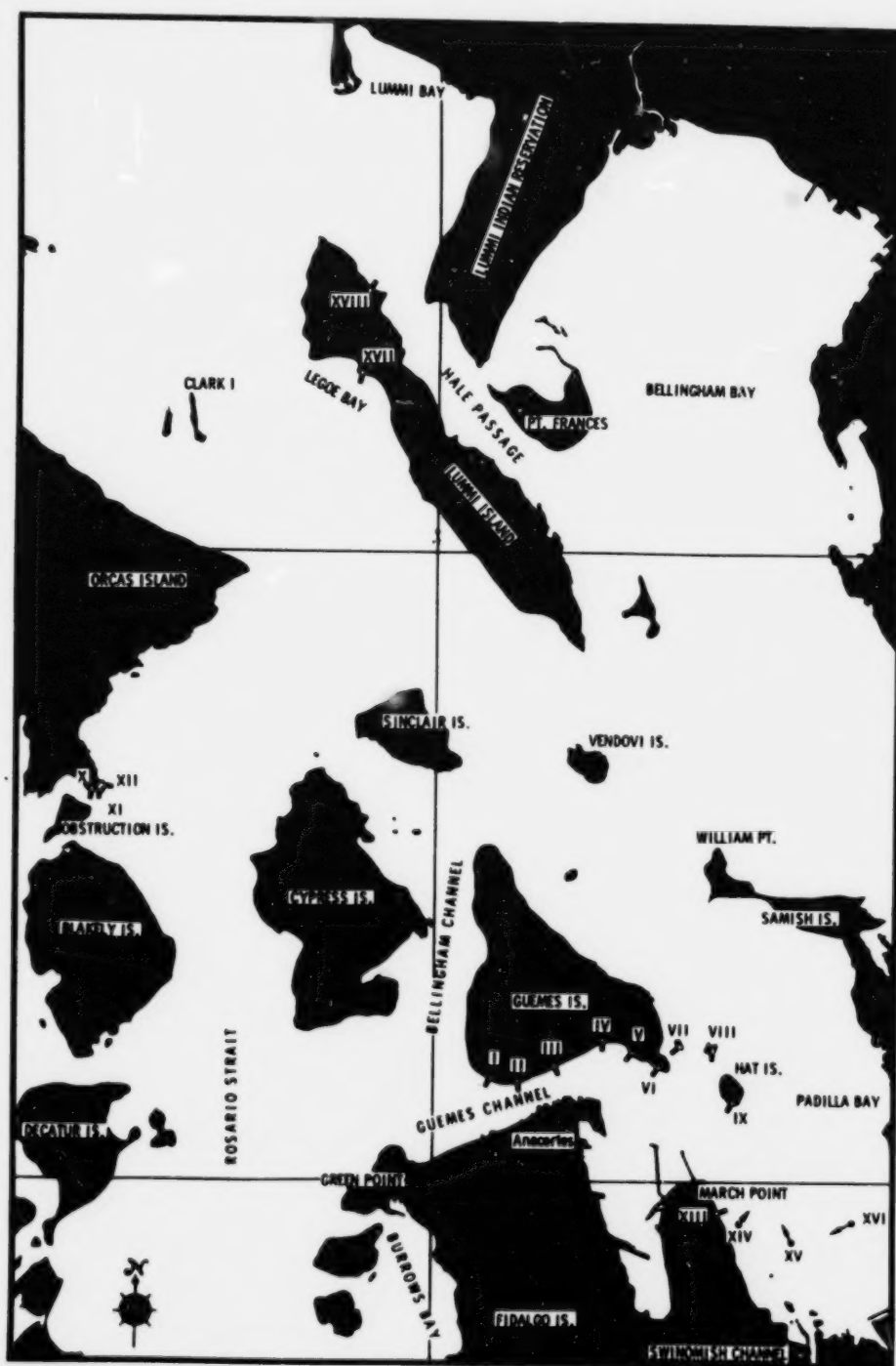


Figure I-2. Shore Traverses and Stations Used for Anacortes Spill



Table I-1
SHORE TRAVERSES AND STATIONS

Shore Traverse No.	Description	Stations	Samples
I	W end of Guemes Island immediately S of N-S road	5	17
II	Guemes Island immediately W of pilings extending offshore 0.4 mi W of ferry landing	6	14
III	Guemes Island 350 yd E of ferry landing at fence and cut through woods	5	16
IV	Guemes Island; steeply tilted bedding structure exposed in cliff 1.8 mi E of ferry landing	6	16
V	Guemes Island; W side of populated cove; fence at edge of cliff; small clearing	5	23
VI	Guemes Island immediately W of SE tip of island at large tree stump	5	16
VII	Huckleberry Island; SW tip	5	16
VIII	Saddlebag Island; cove on S side of island	5	22
IX	Hat Island; small cove on SW side of island	5	20
X	Orcas Island; SW side of Deer Point; small cove adjacent to beach in front of small settlement	5	22
XI	Orcas Island 200 yd W of Deep Point immediately below large mansion on cliff	6	20
XII	Orcas Island; large cove on NE side of Deer Point	5	19
XIII	Fidalgo Island 0.5 mi S of March Point, Padilla Bay	1	5
XIV	Offshore traverse, Padilla Bay, 48° 29' 19" N, 122° 32' 43" W; approximately 0.75 mi S of March Point and 300 yd offshore	1	5
XV	Offshore traverse, Padilla Bay, 48° 29' 01" N, 122° 31' 21" W; approximately 1.75 mi SE of March Point	1	5
XVI	Offshore traverse, Padilla Bay, 48° 29' 20" N, 122° 29' 53" W; approximately 1 mi W-NW of Bayview	1	5
XVII	Lummi Island; W side; 300 yd SE of E point of Legoe Bay	5	17
XVIII	Lummi Island; E side; 500 yd W of Lummi Point	5	21



SECTION II

DATA COLLECTION, ANALYSIS, AND INTERPRETATION

A. DATA ON CURRENTS

The San Juan Islands are situated at the junction of the Straits of Georgia and Juan de Fuca (Figure I-1). The current regime in this region is extremely complex. The primary drive is the tidal current system, which is significantly influenced by the rugged topography of the San Juan Archipelago and the confluence of different water masses. The flood tide advances from the Strait of Juan de Fuca through the San Juan Islands into the Strait of Georgia. During the ebb tide, the direction is reversed. The Haro and Rosario Straits are the primary channels for water movement through the San Juans. Studies by Herlinveaux (1954) and Herlinveaux and Tully (1961) indicate a net seaward current in the Strait of Juan de Fuca in the upper 70 m, with a net inward movement below this depth. Tully and Dodimead (1957) calculated a net northward movement of water in Rosario Strait and a net southward movement through Boundary Pass and Haro Strait. The net movement of water through the three channels as a complete system is seaward.

There are three types of water masses in the Strait of Juan de Fuca-Georgia complex (Waldichuck, 1957):

- The slightly stratified water of Juan de Fuca
- The highly stratified water of the Strait of Georgia, which results from the discharge of the Fraser River
- The vertically mixed water of the passages of the San Juan Archipelago, the result of tidal mixing

Marking the advance of flood tides are complex tide rips (Tully and Dodimead, 1957) which develop at the boundaries between the more stratified strait waters and the homogenous waters in the island passages.



The site of the diesel spill is near the eastern terminus of Guemes Channel situated on the east side of Rosario Strait. Tidal ranges and times for the 36-hr period immediately preceding and during the spill are shown in Figure II-1 (USC&GS, 1971a). Tide curves are shown for Guemes Channel, Swinomish Channel at the entrance to Padilla Bay, and Ala Spit in Skagit Bay. The tides have a marked semidiurnal inequality. As noted by Sylvester and Clogston (1958), the higher high tides in Skagit Bay (Figure II-1) produce a head differential and a portion of the ebb flow passes through Swinomish Channel into Padilla Bay. In Anacortes Channel, the mean tidal range is 4.8 ft, the diurnal range is 8.2 ft, and the mean tidal level is 5.0 ft (USC&GS, 1971a).

Figure II-2 (USC&GS, 1971b) plots the tidal currents immediately preceding and during the spill. Included are data from the west entrance to Guemes Channel, 0.5 mi north of Huckleberry Island, and 0.8 mi northwest of Green Point, Fidalgo Island. Tidal current 0.5 mi east of Guemes Island is too weak and variable to be predicted, and tidal current in Padilla Bay 0.8 mi northwest of March Point is predominantly nontidal, flowing in a northwesterly direction with a maximum velocity of 1 knot (USC&GS, 1971b).

Sylvester and Clogston (1958), in a study for Texaco, Inc., included data by Rattray (1957) on a detailed current survey in the vicinity of the Texaco loading wharf. The numbers above the tidal curves in Figure II-2 refer to illustrations in Figure II-3 which are taken from Sylvester and Clogston (1958) indicating surface-current measurements during the tidal cycle. In applying Rattray's 1957 data to the tidal cycle during and immediately after the spill (Figure II-3), one sees that water movement for the most part is to the northwest toward Guemes Channel. This explains why Padilla Bay appears to have been relatively unaffected whereas the south shore of Guemes Island was heavily contaminated with diesel.

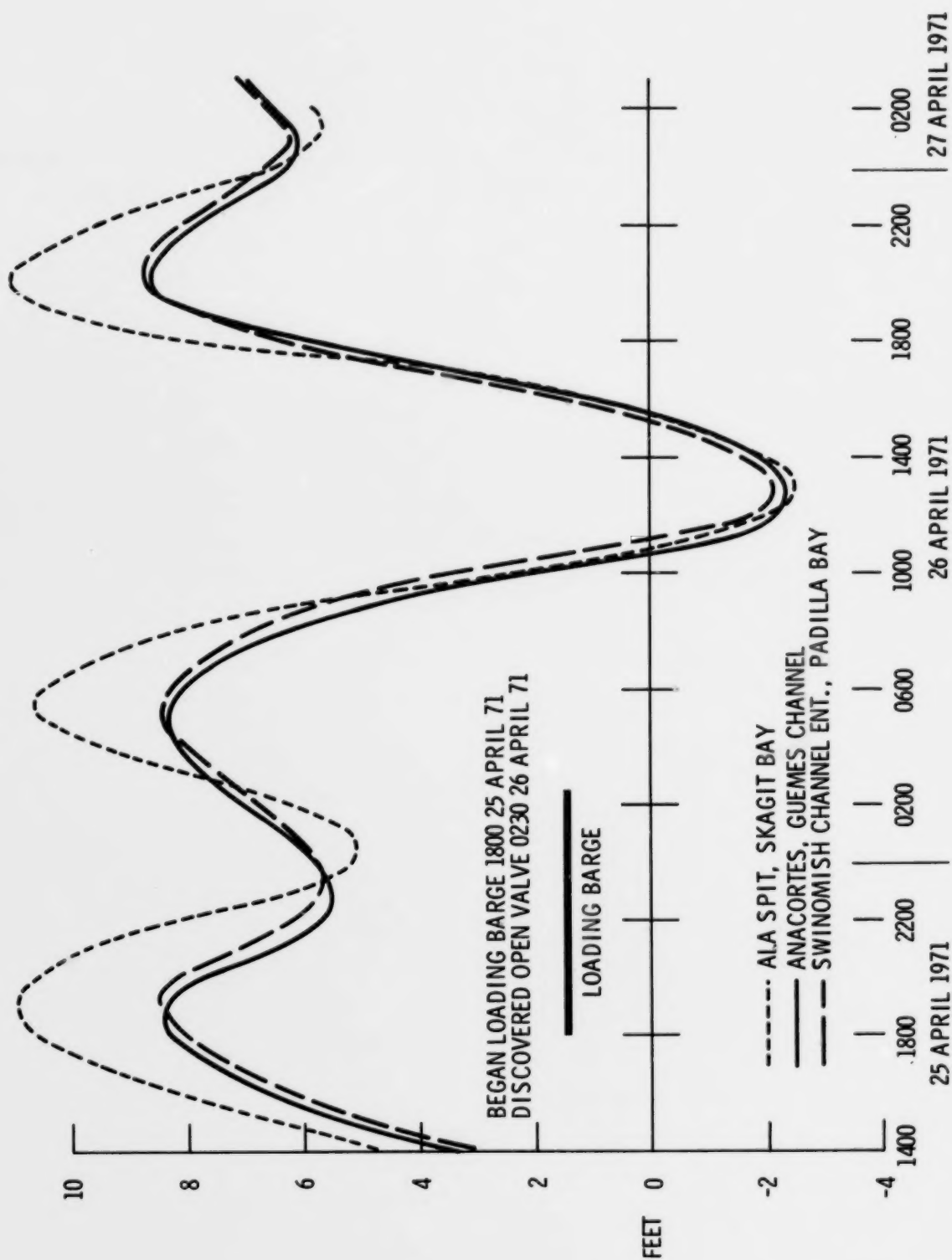


Figure II-1. Tidal Ranges and Times in Vicinity of Anacortes, Washington, USC&GS 1971 Tide Tables

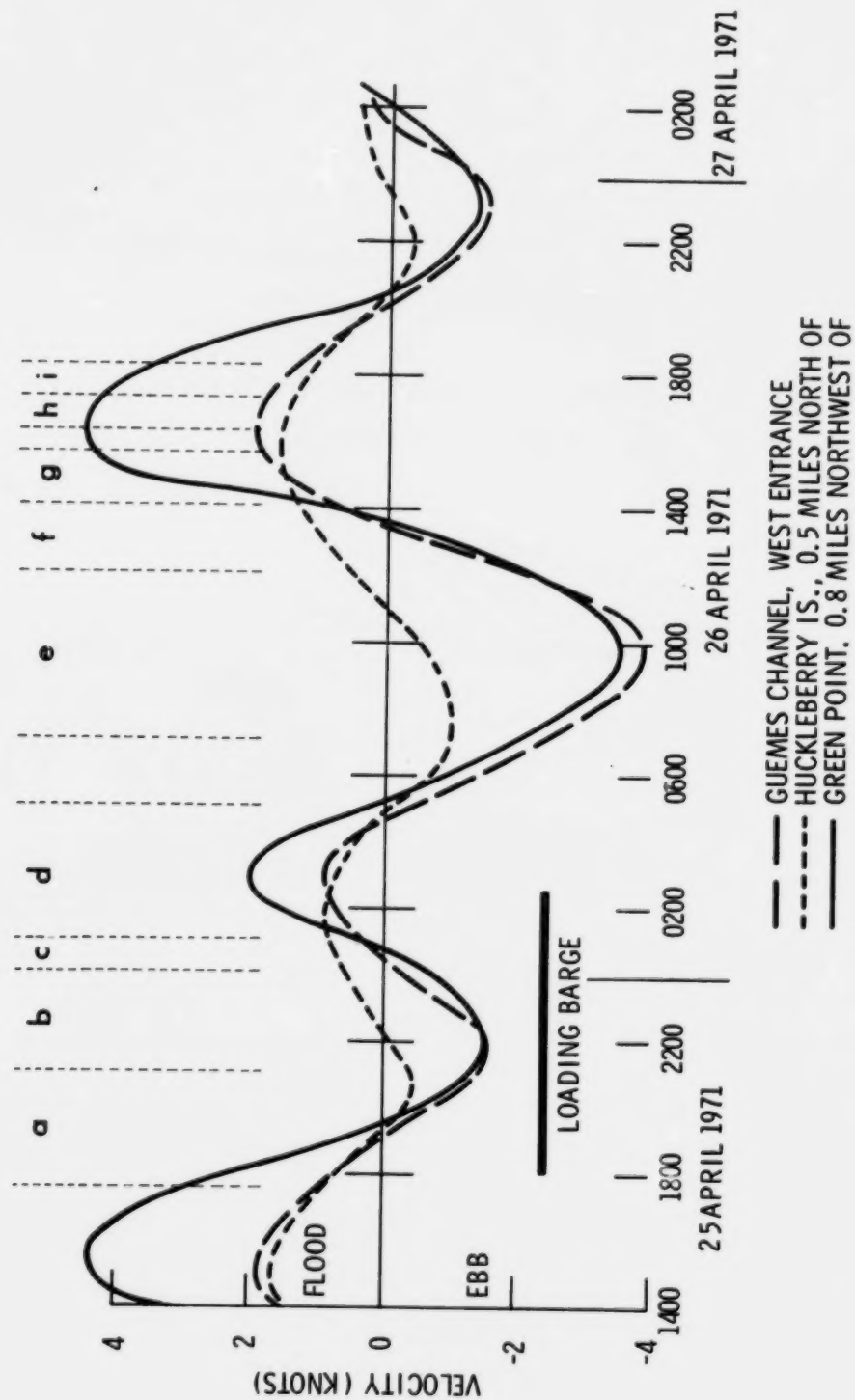


Figure II-2. Tidal Currents and Times in Vicinity of Anacortes, Washington, USC&GS 1971 Tidal Current Tables

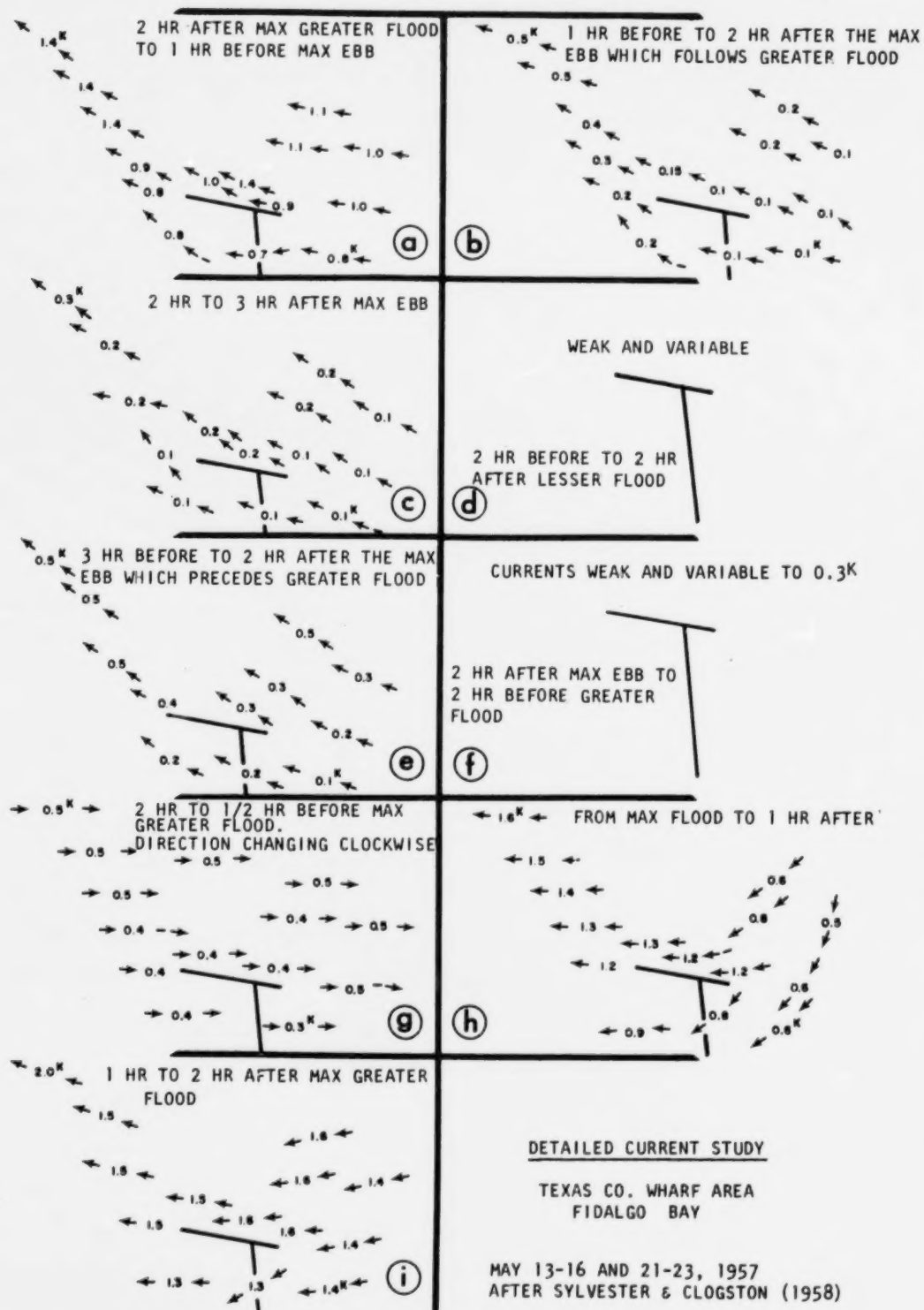


Figure II-3. Detailed Current Study in Vicinity of Texaco Pier
(after Sylvester and Clogston, 1958)



Figure II-4 is a summary current chart for the area in the vicinity of the diesel spill; it and the following description of the currents are from Sylvester and Clogston (1958).

During weak floods or at the beginning of strong floods, the surface currents flow eastward through Guemes Channel, moving radially into Padilla and Fidalgo Bays and northward through the channel between Huckleberry and Saddlebag Islands. During strong floods, the surface currents extend to Hat Island where they divide into strong northerly and southerly components. The strong southerly component produces a back eddy which sweeps along the refinery piers and back into Guemes Channel (Figure II-4); the northerly component of the strong flood passes through the channel between Huckleberry and Saddlebag Islands. During ebb tides, water movement from Padilla and Fidalgo Bays and the channels between Huckleberry, Saddlebag, and Hat Islands creates a strong current which flows westward through Guemes Channel. Surface currents flow northwestward past the refinery piers.

Sylvester and Clogston (1958) computed inflow and outflow for Fidalgo and Padilla Bays for 10 and 11 September 1958 and considered the computations to be roughly representative of the normal water-mass movements in the area. On a flood tide, the discharge volume through Guemes Channel is slightly greater than the intertidal volume of Padilla and Fidalgo Bays, resulting in a small portion of the water mass moving northward of William Point from Padilla Bay and a very small amount passing through Swinomish Channel. On an ebb tide, Guemes Channel passes from two to three times the volume of water that lies in the intertidal prism of Fidalgo and Padilla Bays; this additional water comes from the area north of William Point. Ebb flow from Swinomish Channel is a minor contributor to the total ebb passing through Guemes Channel.

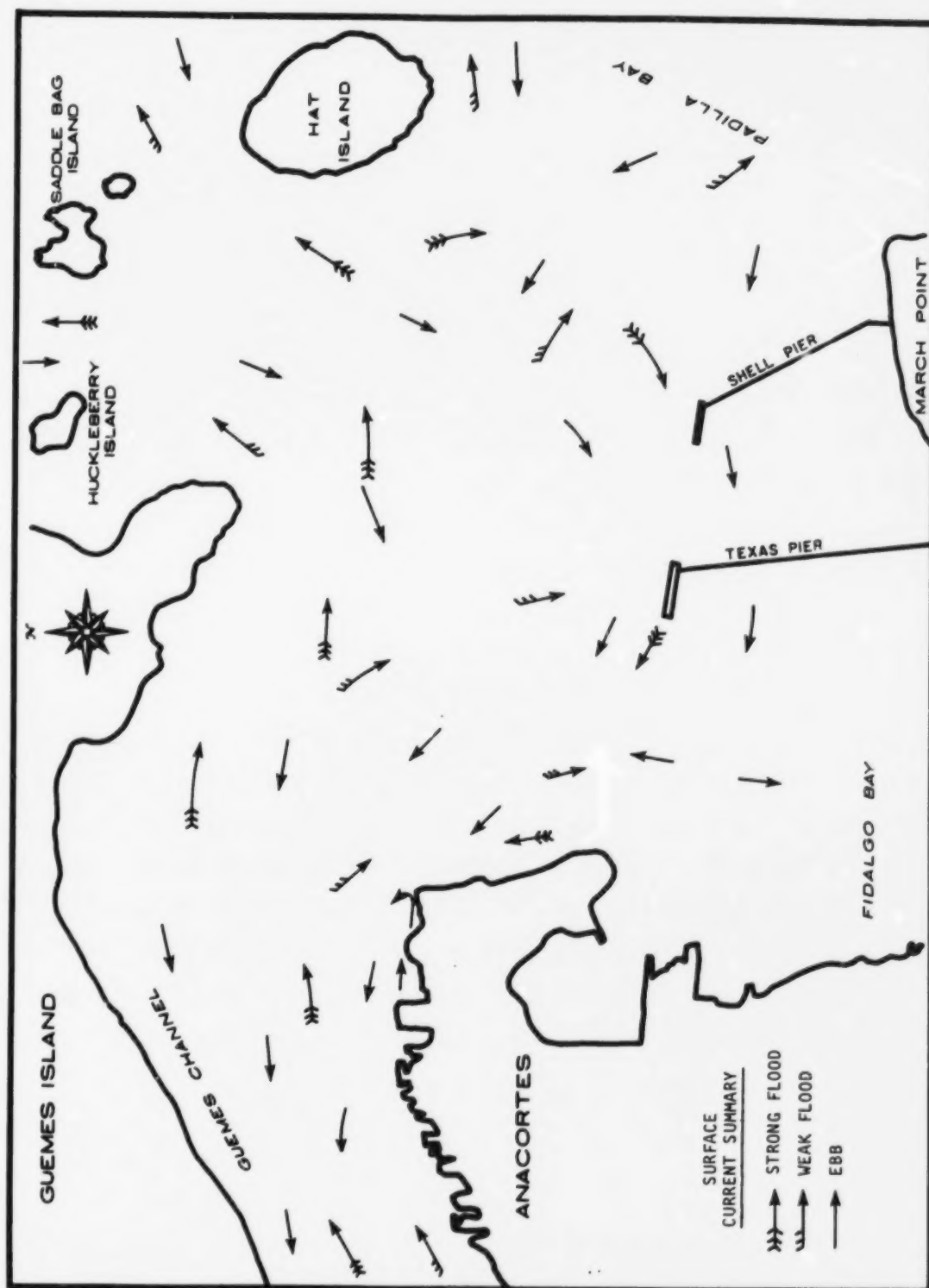


Figure II-4. Summary Surface Current Chart in Vicinity of Anacortes, Washington (after Sylvestre and Clogston, 1958)



In summary, the currents in the vicinity of the spill site are strongly flushing seaward during the ebb tide. Once seaward of Guemes Channel, however, some net water movement northward in Rosario Strait may exist, which could distribute Guemes Channel water northward. On a weak flood tide, a slight amount of water moves north of the small islands east of Guemes. On a strong flood, the current divides near Hat Island with a component flowing north past William Point.

B. CHEMICAL ANALYSIS

1. Introduction

Water, sediment, and biological samples were obtained at each station for hydrocarbon analysis and a number of the samples were subsequently selected for detailed analysis. Those chosen were roughly one-third each of the three sample types. Selection depended on several factors: some of the beaches were composed of cobbles and boulders, precluding effective sediment sampling; some lacked interstitial water; and some were barren of biologic specimens. Another factor influencing sample choice was the time lag between the spill and the actual survey (13 days). The generally strong flushing action of the tides in the spill area removed most of the spill material except that exuding from sediments near shore. As previously observed by Blumer et al (1970), the oil remaining in the area largely existed in the sediments, a small amount being released on each tidal cycle. Sediment analyses, which are discussed in the following subsection, provided the greatest detail on hydrocarbon concentration in the impacted area.

Table II-1 lists the sample types and positions along the shore traverses for the 18 samples analyzed. Also analyzed were reference and weathered surface samples provided by EPA personnel. In addition, two local diesel samples were analyzed for comparison.



Table II-1

SAMPLES ANALYZED FOR HYDROCARBONS

Location	Traverse	Shore Position	Sample Type	Sample No.
Guemes Island	I	MIT ¹	(I) Water ²	8
	II	LIT ³	Sediment	22
	III	UIT ⁴	Sediment	34
	IV	UIT	Sediment	52
		MIT	Biology	45
	V	MIT	(I) Water	120
		LIT	Sediment	112
	VI	LIT	Sediment	103
		MIT	Biology	106
		SST ⁵	Water	74
Huckleberry Island	VII	MIT	Sediment	86
Saddlebag Island	VIII	LIT	Sediment	92
Hat Island	IX	MIT	Sediment	143
Orcas Island	X	UIT	(I) Water	156
	XI	UIT	Biology	174
	XII	LIT	(I) Water	195
Padilla Bay	XIV	Trawl	Biology	219
	XVI	Trawl	Biology	229
Lummi Island	XVII	MIT	Sediment	287
	XVIII	LIT	Water	298
¹ Middle intertidal ³ Lower intertidal ⁵ Shallow subtidal ² Interstitial water ⁴ Upper intertidal				

Table II-2

ADDITIONAL WATER SAMPLES ANALYZED FOR HYDROCARBONS

Location	Traverse	Shore Position	Sample Type	Sample No.
Guemes Island	IV	UIT	(I) Water	54
Guemes Island	V	UIT	Water	64
Lummi Island	XVIII	SST	Water	293
Orcas Island	X	MIT	(I) Water	162
Guemes Island	I	UIT	(I) Water	3



The analyses were made using a Varian Model 1520 Aerograph, a gas chromatograph with linear temperature programmer, flame ionization detector, and 1/8-in., 5-ft columns packed with 1070 dexsil 300 GC on 80/100 mesh chromasorb P. The signal was processed using the Varian 480 integrator, and the log signal was recorded. The digital data from the integrator were stored in a small online computer and read out on a teletype printer after each run. Analyses were made at temperatures from 150°C (with a 5-min hold) to 380°C at a rate of 20°C/min. At 380°C, there was a 20-min hold to clear the column.

An estimate of the composition of oil in the sample was made by comparing the height above background of the $n\text{-C}_{14}$ internal standard peak to the height of the $n\text{-C}_{15}$ peak. To establish a calibration curve for this measurement, four standards were prepared by mixing known volumes of diesel oil and $n\text{-C}_{14}$ in water and extracting this oil with pentane. The height of the $n\text{-C}_{14}$ peak (A), above the background, was approximately the same as the $n\text{-C}_{15}$ peak (B) in the oil samples without the $n\text{-C}_{14}$ internal standard. Thus, the following equation was used:

$$\frac{A - B}{B} = k \frac{[n\text{-C}_{14}]}{[\text{oil}]}$$

Using the standards, k was determined. It varied between 1.6 and 2.5; thus, the method did not prove to be extremely accurate but did give an approximation as to the oil composition. A value of $k = 2$ was used in this work.

Two other sources of error were encountered using this internal standard. First, some samples exhibited a major component near the $n\text{-C}_{14}$ peak, and this component was not easily resolved. Second, the extraction procedure usually resulted in significant loss of $n\text{-C}_{13}$. Thus, it must be assumed that more $n\text{-C}_{14}$ than $n\text{-C}_{15}$ was lost from the oil; however, normal standardizing procedures using well-defined extraction methods should have compensated for this effect.



In future work, $n\text{-C}_{20}$ will be used as the internal standard since none of these sources of error occur in this region. Preliminary work shows that this standard will give more accurate quantitative data.

2. Laboratory Techniques

a. Water Samples

Initial work on standard water samples made up in polyethylene bottles showed that more than 90 percent of the dispersed oil was absorbed on the walls of the bottle. This indicated that the pentane extraction should be made in these sample bottles. Thus, the water was extracted by adding 25 ml of pentane to the water sample. The volume of the sample was estimated by using known volumes in similar bottles. An internal standard, $n\text{-C}_{14}$, was added with a lambda pipette to give a concentration of $0.5 \mu\text{l/gm}$ of water. The bottle was rolled on its side for several minutes, and the pentane was evaporated with a refluxing column until only a few drops remained. This was transferred to a small sample vial using a new disposable syringe.

The above procedure for extracting oil from the water samples was developed using a nonlinear polyethylene sample bottle. The bottles in which the actual samples were collected, however, were coarse linear polyethylene bottles and the normal procedure was subject to interferences because the pentane extracted polymor impurities from the bottle, thus obscuring the GC peaks from any oil that might have been in the water. Five new samples (Table II-2) were then selected and analyzed to a revised procedure. In the revised procedure, the contents of the sample bottles were transferred to a glass container; if the samples had some sediment in them, this was also transferred. A few microliters of normal tetradecane ($n\text{-C}_{14}$) were added as an internal reference. The samples were extracted with pentane and the pentane was evaporated, under reflux, to a few drops. The gas chromatographs were run identical to the first work.



b. Sediment Samples

Between 100 and 250 gm of the sediment samples were weighed into a beaker and $n\text{-C}_{14}$ added to give a concentration of $0.5 \mu\text{l/gm}$ of sample. The mixture was stirred with a glass rod to insure mixing of the standard. Then, the sediment was covered with pentane and placed in an ultrasonic cleaner for 1 hr and stirred frequently with the glass rod which remained with the sample. The pentane was poured off and evaporated to a few drops under reflux.

c. Biological Samples

These samples (crabs, shrimp, and shell organisms) were shucked and cut into small pieces. The extractions were made in a Soxhlet extractor — first using methanol and then pentane similar to the procedure outlined by Blumer (1970). The combined solvents were separated and the methanol extracted with pentane several times. The pentane was then evaporated in a reflux system until the temperature of the sample changed from 36°C . The sample was then evaporated at room temperature until only a few drops remained. During the Soxhlet extraction, $20 \mu\text{l}$ of $n\text{-C}_{14}$ were added to the organisms.

The pentane, methanol, and tetradecane used in all of this work were semiconductor grade or analytical grade. All three were analyzed by the gas chromatograph under the same conditions as employed for sample analysis. The impurities were found to be very low and could not lead to poor analytical results.

3. Results

a. Oil Samples

Gas chromatographic analyses of four diesel oil samples were made from the following:



- Weathered sample extracted from water near the pier where the spill occurred
- Reference sample of oil obtained from a freighter being loaded at the pier a few days later. (Eicosane was added as an internal standard)
- Oil purchased at Plano, Texas, at a Fina service station
- MF diesel oil from TI's laboratory. (This had been there for at least 5 years)

The gas chromatographs of these oils are shown in the top set of plots in Figure II-5. The peaks marked T (following Blumer's [1970] convention) are isoprenoid alkanes; the major peaks are the normal paraffins. These chromatographs give a detailed fingerprint of the oil, which can be searched for in the samples taken in the spill area. It is important to note that there is little difference between the chromatographs; therefore, to positively pinpoint the origin of any oil found in the survey samples would be possible only with a great deal of additional laboratory work.

Figure II-5e shows the chromatograph of a pentane solution of one of the standard samples which we took and extracted. This sample had 50 μ l of diesel oil (extracted from the water near the Texaco pier), 25 μ l of tetradecane, and 250 ml of water.

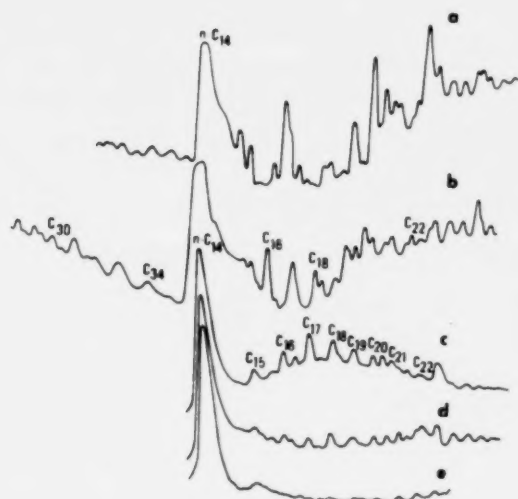
b. Water Samples

In Figure II-5, top left, typical gas chromatographs of the extracted material from water samples are shown. The large complicated peaks observed cover any oil peaks which might be present. These peaks were obtained on all water samples. The bottom curve in this portion of the figure shows the gas chromatograph of a pentane extract made from the inside of one of the clean water-sample bottles. These peaks correspond to those found on the chromatograph of the water samples. The masking effect results from reaction between the pentane and polyethylene bottles used for sample collection. Future samples should be collected in glass containers.

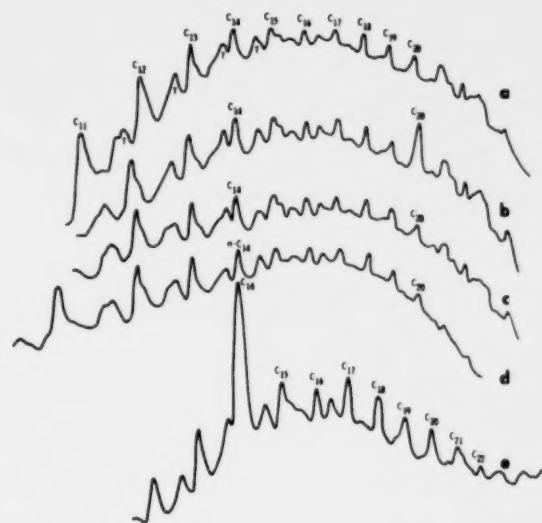


TYPICAL GAS CHROMATOGRAPHS OF HYDROCARBONS EXTRACTED FROM WATER SAMPLES. REACTION OF PENTANE WITH POLYETHYLENE SAMPLE BOTTLE MASKS HYDROCARBON IDENTIFICATION

(a) PENTANE EXTRACTION OF CLEAN SAMPLE BOTTLE

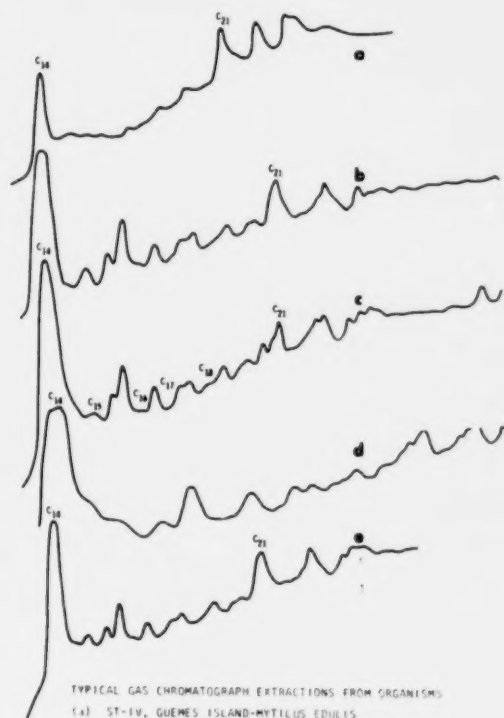


GAS CHROMATOGRAPHS OF HYDROCARBONS EXTRACTED FROM ADDITIONAL WATER SAMPLES UNDER REVISED PROCEDURE



TYPICAL GAS CHROMATOGRAPHS OF SOURCE AND TYPICAL DIESEL OILS

- (a) OIL EXTRACTED FROM WATER TAKEN NEAR REFINERY PIER
- (b) SOURCE SAMPLE OF NO. 2 DIESEL OBTAINED FROM TEXACO REFINERY
- (c) NO. 2 DIESEL FROM FINA STATION, PLANO, TEXAS
- (d) HP DIESEL FROM QRA LABORATORY, TEXAS INSTRUMENTS
- (e) PENTANE SOLUTION OF STANDARD SAMPLE



TYPICAL GAS CHROMATOGRAPH EXTRACTIONS FROM ORGANISMS

- (a) ST-IV, GUERES ISLAND-MYTIUS EDULIS
- (b) ST-VI, GUERES ISLAND-HEMIGRAPHUS NUDUS
- (c) ST-RI, ORCAS ISLAND-MYTIUS EDULIS, ACHIA sp.
- (d) ST-XIV, PADILLA BAY-PAGETTIA GRACILIS, CRAGO sp.
- (e) ST-XVI, PADILLA BAY-PAGETTIA GRACILIS, CRAGO sp.

Figure II-5. Gas Chromatographs



Because of the ambiguous results obtained in the original efforts, five additional water samples were run. Figure II-5, bottom left, illustrates gas chromatographs of the new samples. Samples 54, 64, and 293 showed diesel-oil fingerprints; the concentration was greatest in sample 54 and least in sample 293. Sample 3 appears to have had normal paraffins beyond C_{34} . Since the diesel oil contained no normal paraffins beyond C_{23} , one must assume that the sample contained traces of some other oil spill(s); crude oils and many processed oils contain these longer chains. The relatively large C_{16} to C_{20} peaks for sample 3 indicate that there might be a large amount of diesel mixed with these heavier oils. Sample 162 gave a completely unexplainable chromatograph; no oil fingerprints could be discerned through all of the strange peaks.

c. Organisms

None of the extracts from the organisms exhibited the diesel fingerprint, although they were similar to each other. An examination of the chromatographs (Figure II-5, bottom right) shows that the major peaks occur between the normal paraffins. Some of these peaks were observed by Blumer et al (1970) for contaminated organisms and were found to arise from an alteration of the oil. The peaks are for the isoprenoid alkanes. The large peaks in the C_{21} region have been shown to be abundant in many algae species and to have an organic origin (Clark and Blumer, 1967). Based on a limited number of samples, it is impossible to state unequivocally that oil was found in these organisms. In light of Blumer's work, it would appear that samples 174, 106, 229, and 45 may contain some altered diesel oil.



d. Sediment Samples

Results of the analysis of the extracted oil from the sediment samples are listed in Table II-3. The gas chromatograms, Figure II-6, are nonambiguous and clearly show the diesel fingerprint. The quantitative results are estimated to have an accuracy of ± 50 percent.

From Table II-3, it is apparent that the south shore of Guemes Island (shore traverses I through VI) was the most heavily contaminated of the areas investigated. Sediments from Huckleberry, Saddlebag, and Hat Islands were contaminated to a much lesser degree, and the west side of Lummi Island had a minor amount. The chemical analysis of the Saddlebag Island sample is difficult to explain inasmuch as diesel odor and sheen were noted at the station.

Table II-3
ANALYSIS OF SEDIMENT SAMPLES

Shore Traverse No.	Sample	Description	Diesel Oil [$\mu\text{g}/\text{Kg}$ (PPB)]
II	22	Sand and gravel	31
III	34	Coarse sand and gravel	120
IV	52	Sand, gravel, and shells	5
V	112	Gravel and shells	480
VI	103	Sand, gravel, and shells	390
VII	86	Silt and shells	12
VIII	92	Fine black sand	3
IX	143	Sand, gravel, and shells	trace
XVII	287	Medium gravel	2

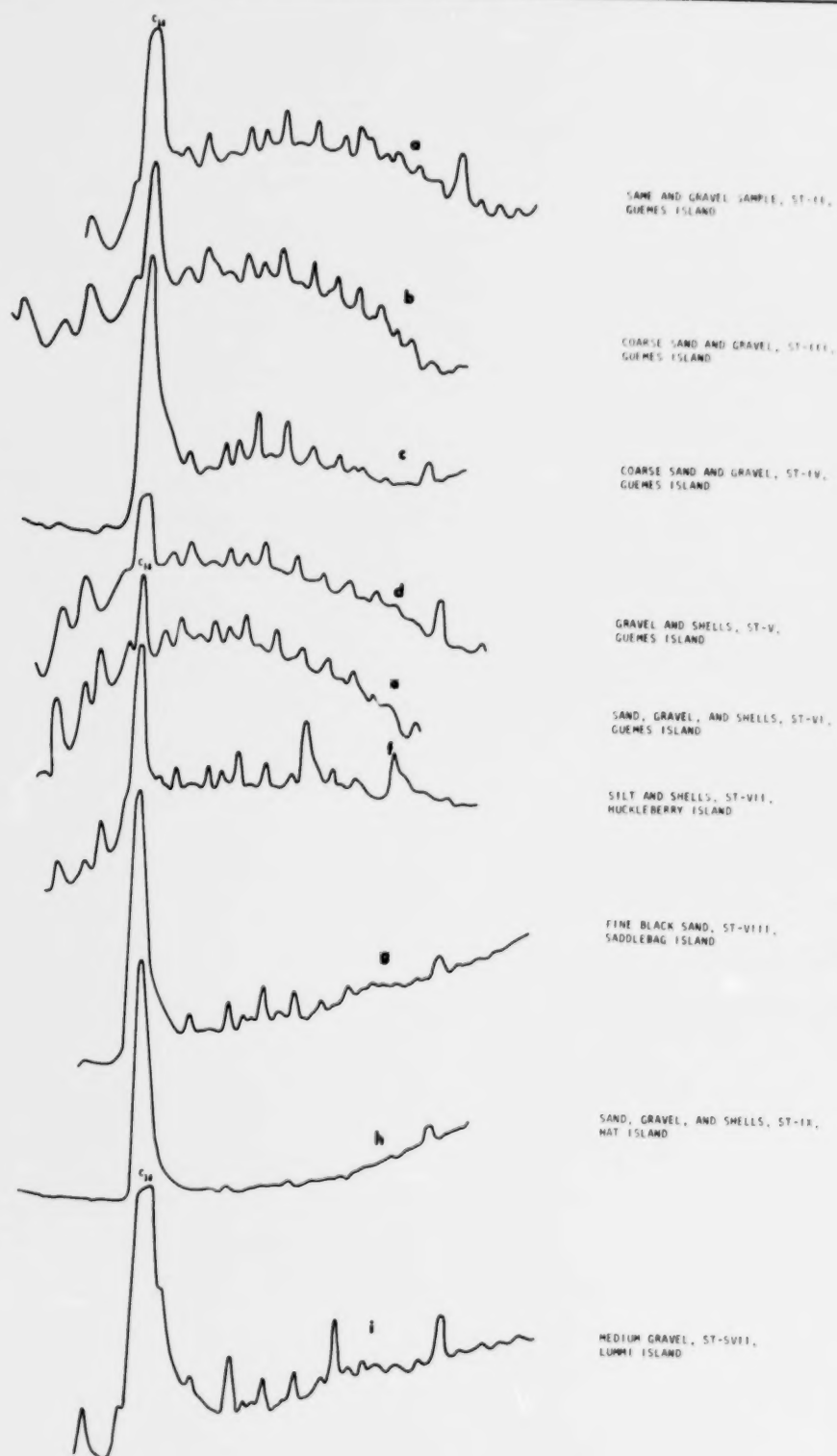


Figure II-6. Gas Chromatographs of Hydrocarbons Extracted from Sediments

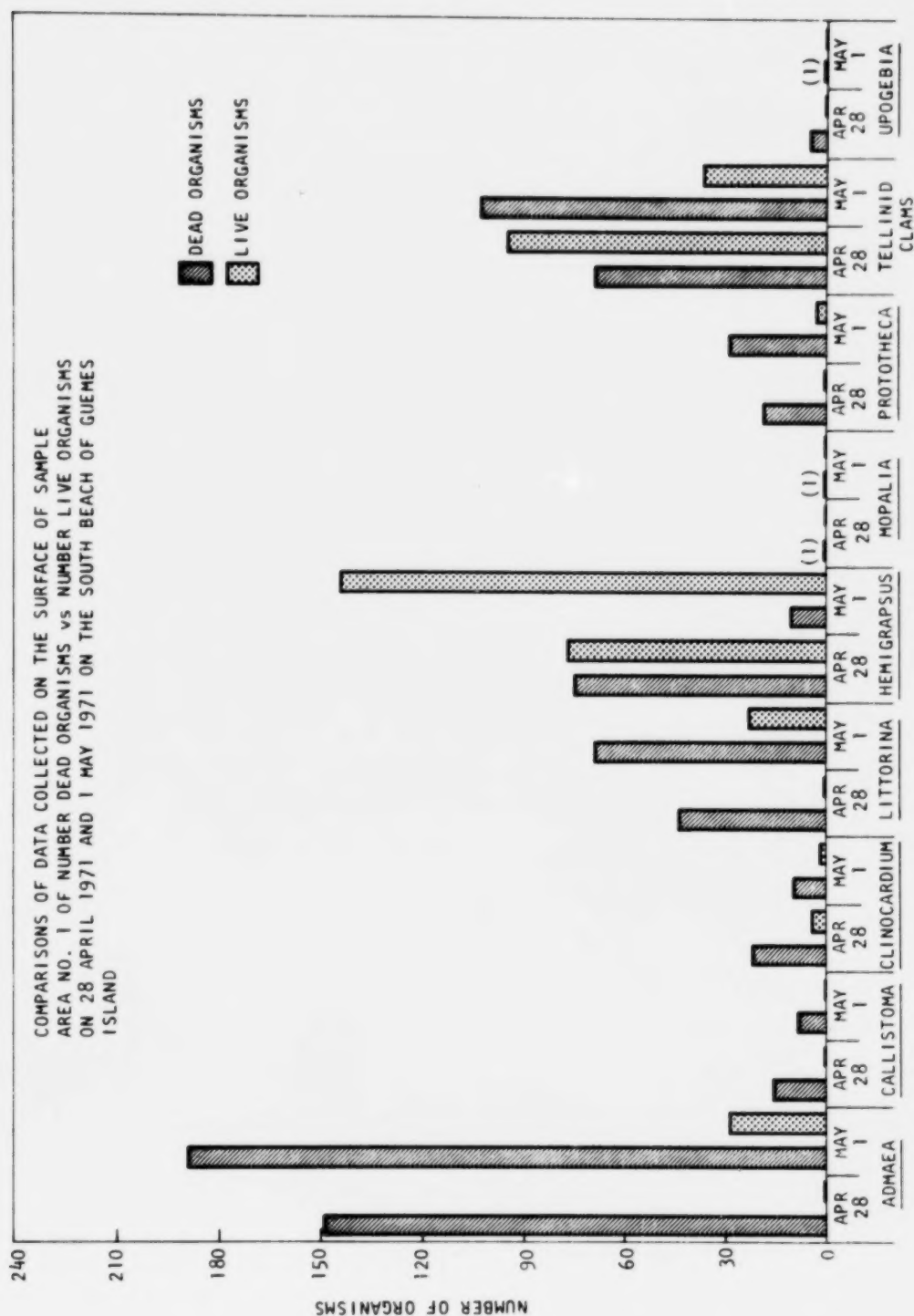


Figure II-7. Comparisons of Data Collected on Surface of Sample Area 1 of Number of Dead Organisms Vs Number of Live Organisms on 28 April 1971 and 1 May 1971 on South Beach of Guerres Island



C. MARINE BIOTIC COMMUNITIES IN THE SPILL AREA

Other state government groups and universities attempted to sample various portions of the spill area, but none of the studies were comprehensive or sufficiently objective to reveal the extensive damage that the spill may have done to the regional biota. Perhaps the most complete study was conducted by Dr. William Berg and Dr. Herbert H. Webber and a number of graduate students from the Huxley College of Environmental Science, Western Washington State College, Bellingham, Washington. This group sampled organisms on the south beach of Guemes Island from 28 April 1971 to 15 May 1971. Data were collected along two sampling areas located approximately 0.75 mi east of the ferry terminal on the south beach of Guemes Island. Their work is included as Appendix A, "Survey of Mortality of Two Areas of the South Beach of Guemes Island, April 28 to May 15, 1971." Of particular value is the description of early mortalities and subsequent kills, apparently resulting from the release of persistent hydrocarbons from within the sediment.

Figure II-7 illustrates a summation of their findings of the surface benthos of area 1. Some mortality was noted among all the species examined, but none of the species revealed complete mortality. The organisms appearing to suffer the greatest mortality were the chitons, limpets, and cockles. Some students will continue studies of the area through the summer.

Other academic personnel from the University of Washington at Seattle carried out a subtidal inspection of the Guemes Island area by diving; they believed, however, that there was no need to return for detailed studies. Also, scientists from the Department of Ecology for the State of Washington performed intertidal surveys, picking up representative specimens of organisms which appeared to have been killed by the spill. Other scientists from the Aquaculture Project of the Lummi Indian Reservation also surveyed the beaches of Lummi Island, where a crustacean kill had been reported (20 ft wide by 2 in. deep, extending the length of the beach). Seven days later, an ecological response team of Texas Instruments Incorporated was asked to survey the San



Juan Island region for evidences of ecosystem damage which may have resulted from the Anacortes spill.

The response team employed a plan of study devised by EPA for a more objective survey of possible ecosystem damage. Traverses perpendicular to the shore and areal surveys of Padilla Bay and Guemes Channel were planned. Quantitative methods of faunal survey were anticipated. Little hydrographic data were to be collected, inasmuch as the residence time of waters in the affected area is minimal. Sampling began on 9 May 1971 and was terminated on 13 May 1971 after a survey of the northern portion of Lummi Island.

1. Methods

Biological sampling in the San Juan Islands area was performed in 18 traverses. Six traverses (Figure I-2) from the upper intertidal to below 10 m in the subtidal region were occupied on Guemes Island, the area known to have received the full impact of the oil spill. Another group of similar traverses (Figure I-2) was on the southeast tip of Orcas Island at Deer Point, an area of similar hydrography but presumably unaffected by the oil spill; this area was considered as the control. One shore sample was obtained on the west shore of Padilla Bay near the station occupied by Sylvester and Clogston (1958) for their baseline study. Sampling was scheduled for all tidal levels, but low tides fell at the wrong time for complete sampling. Subtidal, however, and what can be considered as low intertidal stations were occupied by grabs and trawls in the central portions of Padilla Bay, as shown in Figure I-2. A final set of shore traverses was occupied at the northwestern end of Lummi Island at the request of EPA and scientists at the Lummi Indian Reservation Aquaculture Project — one on the west side and another on the east side (Figure I-2) — to verify reports of environmental damage to crustacean (mysid and euphausid) populations in these coves.



All traverses except the central Padilla Bay stations were occupied in the same manner. Quadrats at each tidal level were photographed and the results visually examined for living animals. All animals large enough to see with the naked eye were picked out and saved for later identification and counting. Also, when possible, a Van Veen sample was taken in the center of each quadrat by forcing the jaws into the beach or by marking an area on the cobbles. All material marked by the Van Veen jaws was removed and brought back to field headquarters, where it was washed through 250- μ pore screens for meiofaunal analysis. Interstitial water samples were taken for hydrocarbon analysis, salinities, and microbiology where water was available. Sediment samples were also obtained for sediment size analyses. While samples were being gathered from the quadrat, a random collection of larger epifauna was made in a 100-yd area within each tidal zone.

For the biology at most of the subtidal stations, the Van Veen grab was used. Water samples were obtained at the surface and bottom with a standard bottom water sampling bottle in which a stopper is pulled from a weighted bottle when it reaches the desired depth, allowing it to fill. Although primitive, this method is quick and effective and requires no special messengers and wire. In areas where bottom conditions were favorable, grab samples were supplemented by taking 5-m otter trawls and 1-m-wide dredge samples. Most of these were at the deep end of the traverses. The equipment is pictured in Figures II-8 through II-10.

The biota were sampled in the same general manner and with the same methods and equipment that the team had used in previous benthic surveys (Parker and Blanton, 1970; Parker, Scott, Berry, and Baker, 1969; and Blanton and Blanton, 1971). Quantitative benthic samples were taken with a $1/25\text{-m}^2$ Van Veen bottom grab. Beach samples were always taken from a $1/2\text{-m}^2$ quadrat placed at random at the various intertidal levels indicated by different faunal communities.

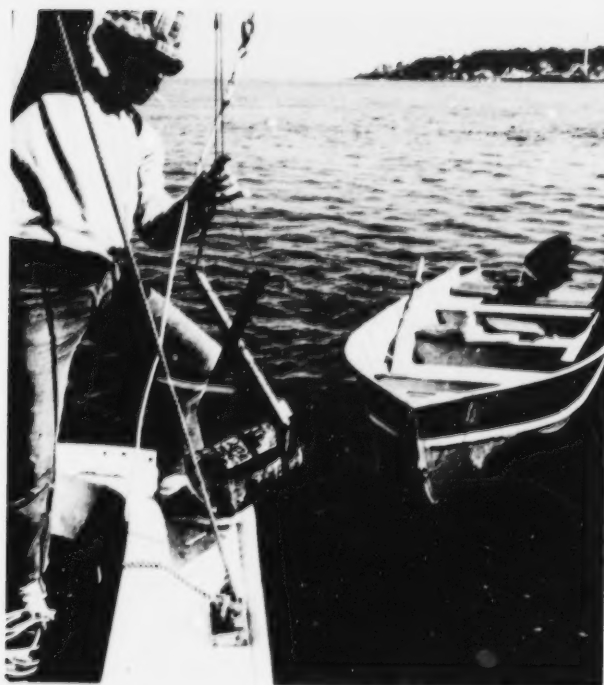


Figure II-8. Two Views of $1/25\text{-m}^2$ Van Veen Grab



Figure II-9. Large Dredge Obtained on Loan from University of Washington



Figure II-10. Two Views of 15-ft Otter Trawl



The quadrat area was marked by a circular length of steel cable enclosing an area of $1/2\text{-m}^2$; this quadrat conformed to the irregularities of a cobble bottom. Although quantitative sampling was attempted at all beach localities, a random collection of visible animals and algae was also made at each intertidal level over a horizontal distance of 100 yd.

Microbiological studies were conducted on sediments from most stations in each shore traverse. Samples were frozen soon after they were collected and then were thawed in the laboratory immediately prior to processing. All procedures were carried out under aseptic conditions in a manner such that the following data could be derived:

- Total number of bacterial cells per cc of sediment, utilizing direct-phase-contrast microscopic counts and a counting chamber
- Total numbers of living cells per cc of sediments, using a Du Pont Luminescence Biometer — an instrument which measures ATP in living cells to an accuracy of ± 1000 cells
- The diversity of different kinds of bacteria as indicated by the variety of colony types from any given sample

The colony types were determined on 72-hr streak plates utilizing 75 percent aged-filtered seawater containing appropriate nutrients and growth factors. Diversity was stated only as the number of different colony types present — not as dominance diversity or based on one of the many diversity indices.

Water samples were taken for salinity determinations using standard titration techniques with AgNO_3 , as set forth by Harvey (1963), and additional chemical analyses. Water samples also were obtained for the bacteriological studies just described.



In the laboratory, all biological samples were sorted as to larger forms (megafauna) and organisms less than 4 mm (meiofauna). Grab samples were sieved in the field with a pore size limit of 250 μ and later screened in the laboratory through a set of precision steel screens graded at 4, 2, 1, 0.5, and 0.25 mm so that approximate organism size relationships could be discerned.

Preliminary identifications have been completed on most of the 300+ samples to major taxa level (order or superfamily). The majority of the megafauna has been identified to species level, although not yet verified through an acceptable study collection.

Almost 3000 animals were identified to genus or to species, and approximately 1,313,600 animals were identified to major taxa level. Some concept of the numbers of organisms checked in this study can be gained through Figure II-11, which is a view of the nearly 1000 vials and bottles used to store the checked material. None of the very small animals in the trawl samples or in the Van Veen grabs have been identified as to species, but this was not important inasmuch as comparisons only can be made with lists compiled by Sylvester and Clogston (1958) and Sylvester, Carlson, Christman, and Oglesby (1966), in which only animals over 1 cm are mentioned. A recent study by Lie (1968) contains a great deal of quantitative information on Puget Sound benthos; however, his samples were taken with a 0.1-m² (1/10) Van Veen grab, which is five times larger than the grab used in the present study. Only animals larger than 1 mm were saved in Lie's study, and most of his samples were taken in depths exceeding 20 m. Lie's sampling traverse, visited once a month, was located near Seattle; thus, environmental conditions were considerably different from those of the Anacortes region. For these reasons, valid comparisons between Lie (1968) and our study would be difficult.



Figure II-11. View of CEM's Previous Laboratory Facilities and Collection of Animals Obtained at Anacortes



2. Results

A baseline study of the Anacortes area, which was made by Sylvester and Clogston (1958), gives a qualitative evaluation of the megafauna in the various habitats and environments near the Texaco refinery site. A later study by Sylvester et al (1966) provides somewhat more detailed biological information for the eastern portion of the San Juan Island region and the mainland shore north of the city of Bellingham, although none of the biological observations were made near the Anacortes-Guemes area. Direct comparisons can be made only in relation to the kinds of animals present during the three sampling periods, and this kind of a comparison is of relatively little value to this study. The presence or absence of a species collected by hand intertidally is a function of an individual's powers of observation. The two previous studies in this region were conducted over a period of several months, while the most recent sampling took only 4 days. Since many organisms have sharp seasonal abundances, it is likely that major discrepancies may arise between species found in the past at different seasons and not found in this study. Some comparisons can be made between these three studies, however, and an attempt has been made to list species (but not abundances) taken in approximately the same locations by this survey and Sylvester (1958) and in the same environment by this study and Sylvester et al (1966).

a. Comparisons between Anacortes Region Faunas Taken in 1958, 1966, and 1971

Much of the 1958 study was devoted to an investigation of the currents and other hydrographic factors in the vicinity of the Texaco refinery. A complete water-quality analysis on a continuing basis for 6 months was also performed since the problem was one of determining the effects of continual



effluents rather than a single industrial disturbance. The biological portion of this investigation was divided into two major parts: a benthic survey of both subtidal and intertidal biota and a plankton survey. Neither survey was quantitative, but comparative abundances were cited which can be used to give rough assessments of major biotic changes since 1958.

Plankton samples were taken by the survey team inasmuch as it would be useful to check larval settlement and appearance during the 1971 sampling program with the same month for the 1958 program.

1) Subtidal Comparison

The 1958 subtidal survey was conducted in March and again in June — sufficiently close in time to make a valid species comparison. Only the dredge hauls in the vicinity of the spill and the trawl hauls in Guemes Channel and near Saddlebag Island are used in the comparison. Hauls deeper than 90 ft were excluded, since the sampling of this survey did not extend beyond that depth.

Table II-4* lists the species of megafauna taken in 1958 at the 90-ft depth and 36- to 45-ft depth off Guemes, the 30-ft depth off Saddlebag Island, and the 13-ft depth in Padilla Bay. Those species taken in 1958 but not in the present survey are starred. At 90 ft, 43 percent of the animal types were absent in the 1971 trawls; at 36 to 45 ft, 60 percent of the animals were not taken in 1971; at 30 ft, 63 percent were not collected; at 13 ft in Padilla Bay, only 25 percent were not taken. Taxa identifications for the present subtidal survey are given in the lengthy compilation of all megafauna identified in Table II-5.

* Included with subsequent tables at the end of this section.



It is unwise to place too much emphasis on the differences between these two surveys inasmuch as different kinds of equipment were used in the two studies. It is perhaps fortunate, however, that the dredge was possibly the same one — or at least of the same design. The percentage of animal species missing in the 1971 study increases toward shore and into shallow water except in the Padilla Bay area. This rather weak observation could be related to the fact that, in this small area under discussion, diesel oil could be detected emerging from the subtidal muds. Since oil would more likely be trapped in the shallower muds than in muds at 90 ft, there is the possibility that species in the shoaler areas were eliminated. It is significant that normal fauna, with the same species found in 1958, were taken in the center and east side of Padilla Bay, which presumably escaped the spill.

2) Intertidal Comparison

No exact lists by intertidal zone were prepared during the 1958 study but, within the narrative, it is possible to determine approximate levels where certain intertidal fauna were taken. It is obvious from comparing the species list from the 1958 study and the one obtained by the present survey that the 1971 collection is much more thorough (Tables II-5 and II-6).

Table II-6 lists all species taken by both groups for each intertidal zone (upper, middle, and lower). The zonation is based on the change in community structure observed on the vertical faces of the cliffs at the edge of Guemes Channel, as shown by the photographs in Figures II-12 and II-13. This type of zonation has been discussed at length by Stephenson and Stephenson (1949), Doty (1957), and Mokyevsky (1960a and 1960b).

The list in Table II-6 reveals little in the way of evidence of environmental damage. In the upper intertidal zone — dominated by barnacles, limpets, and Littorina — 12 kinds of animals were taken in 1971, whereas only seven were observed in 1958. The two species not seen in 1971 are wood borers, which were probably present inside the pilings and other wood along shore.

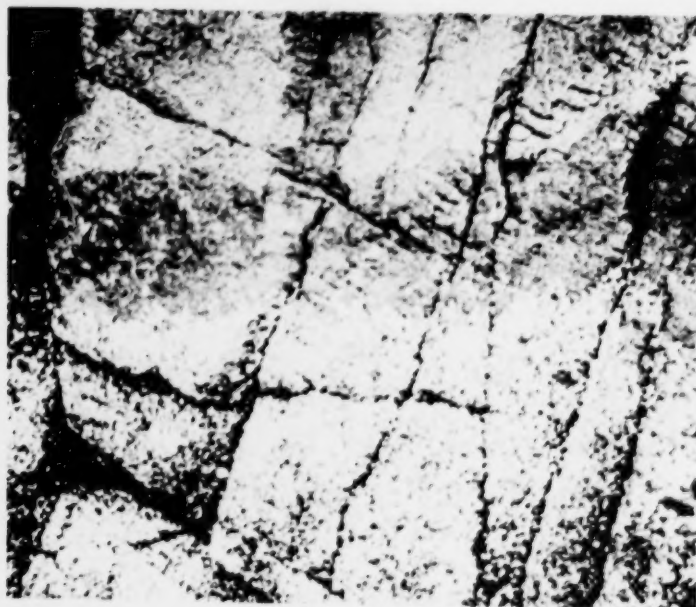


Figure II-12. Intertidal Zonation as Revealed on Vertical Rock Surfaces on Saddlebag Island



Figure II-13. Intertidal Zonation Typical of More Horizontal Rock Surfaces on Guemes Island



A lengthy list of 22 taxa was compiled from the 1971 observations in the middle intertidal zone; only 12 species were reported in the 1958 study. Three species of large and conspicuous invertebrates were reported in 1958 but not observed in 1971, which may be significant. Two of them, Callianassa californiensis and Cucumaria miniata, would be particularly susceptible to foreign substances in the water because of their particular biological requirements for clean water. The lower intertidal zone has the highest diversity, with at least 27 different kinds of animals in 1971; on the other hand, only eight were reported in 1958, and nearly half of those were not found in 1971.

3) Comparisons between Intertidal Faunas of 1966 and 1971

A more recent comparison between intertidal faunas is possible through the 1966 study. The collections were made primarily along the mainland near Ferndale, Washington, some distance north of Anacortes and even north of the 1971 northernmost traverses on Lummi Island. The list of species from the 1966 report is presented in Table II-7; this table gives only those species not observed in 1971 but found either in 1958 or 1966 in that region. Of the 47 intertidal species reported in 1966, only seven were not taken in 1971; on the other hand, the 1958 survey revealed that 21 species were found then and not taken in 1971. The only real conclusion one can draw from these data is that the 1958 collectors may have been more observant or better trained in systematics than those collecting in 1966. The shore traverses on Lummi Island were particularly poor in animal life, with only a few species being found anywhere in the intertidal region. Conversations with the Lummi Island Aquaculture scientists revealed that this area always has a poorly developed intertidal fauna. No reasons except high turbulence resulting from tidal interference phenomena were given for poor standing crops.



4) Conclusion

Using as evidence the comparison between the narratives and lists given in the 1958 and 1966 baseline studies and the 1971 investigation, it is difficult to say whether any damage has been sustained in the intertidal zone of the region studied. On the other hand, it is also evident that considerable biological disruption was observed in 1971 but was not adequately quantified. For instance, in most of the traverses on Guemes Island and especially the traverse on Saddlebag Island, considerable quantities of oil exuding from the sediment and from under rocks was observed by this investigating team. The oil seepage was photographed a number of times; the best examples are shown in Figures II-14 through II-17. Although one cannot state that the oil has killed any of the organisms (based on the observations), large numbers of snails were completely narcotized at these locations. (See the complete list of megafauna, Table II-5, and the field notes in Appendix B.) Scientists at Western Washington State College, Bellingham, report that these snails (Thais) completely revived when placed in clean seawater.

More evidence that the intertidal communities had been damaged in traverses II, III, IV, V, and VIII was the almost complete lack of large and small clams (Pelecypoda). Biologists from the state and federal agencies investigating the spill remarked that many of the clams died soon after the spill. Few live specimens of any species were taken during the survey; those few obtained are listed in Table II-5. Unusually large numbers of small crabs were found dead on the beaches at these traverse locations. Also, fairly large numbers of dead shore crabs were observed at most of the other traverses. These crabs may have a natural mortality at this time, but this must be verified through local experts.

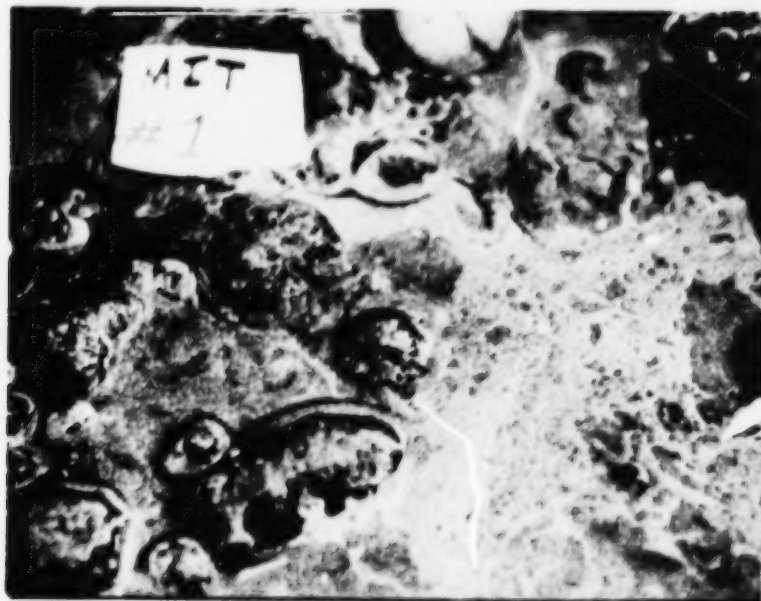


Figure II-14. Examples of Oil Sheen and Rainbows at Guemes Traverse II



Figure II-15. Examples of Oil in Tide Pools and
along Shore at Guemes Traverse V



Figure II-16. Subtidal Oil Seepage at Saddlebag Island



Figure II-17. Concentrations of Snails (Thais) Narcotized by Oil Present on Beach

Chitons are usually a conspicuous part of the intertidal region in this area, but it was noticed that they were rare during the 1971 survey of Guemes and the three small islands although not in the control area. Few amphipods were observed; also rarely seen were the large limpets, snails, anenomes, and tunicates. It would seem that most of the larger invertebrates normally exposed to ionic changes in the water (soft tissues exposed for long periods) were missing or rare, suggesting that these forms could have been severely affected by the brief spill and the lingering effects of the oil infused into the substrate. Inasmuch as the comparisons between former studies (1958 and 1966) and the present one (1971) yield little concrete data concerning possible ecosystem damage, burden of proof falls upon comparisons of the data from this survey in the areas known to be affected and in the control traverses.

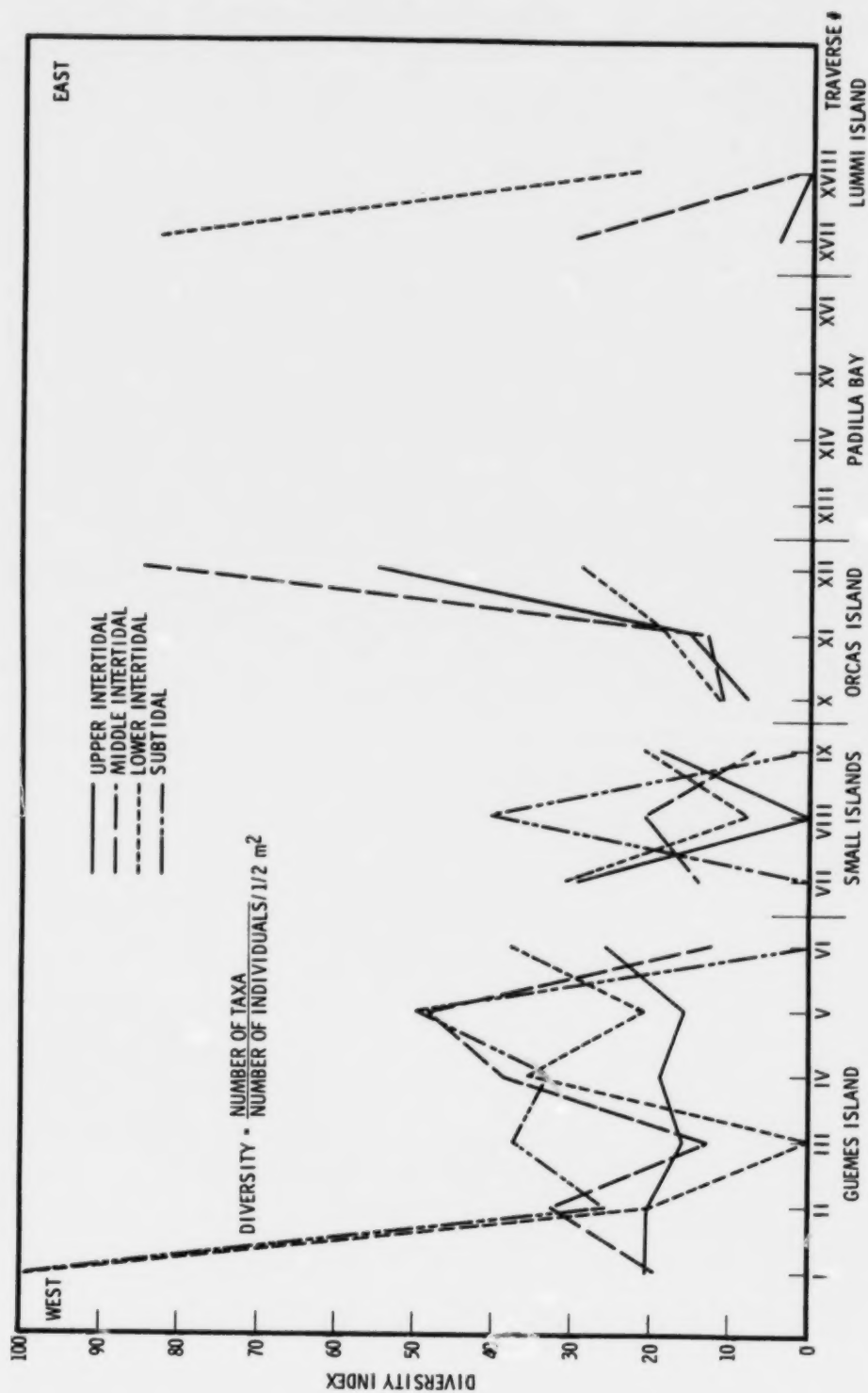


Figure II-18. Simple Diversity Calculations for Megafauna Based on 1/2-m² Quadrats. Data are not presented for Padilla Bay, since only trawl and grab samples were taken.



b. Diversity and Density, 1971 Data

1) Megafauna

Most of the intertidal megafaunal data are not strictly quantitative, although there has been an attempt to pick out all visible organisms in $1/2\text{-m}^2$ quadrats at each intertidal zone. Results of these counts are shown in Table II-5, which lists the species and number of individuals for each species. Some of the samples listed are random collections of no quantitative value. The epifaunal or quadrat samples are considered to be quantitative. Using the ratio of the number of taxa to the number of individuals at each station, simple diversity indices were calculated on the latter samples. In all cases, diversity for megafauna is calculated as

$$\text{diversity} = \frac{\text{number of taxa}}{\text{number of individuals}/\frac{1}{2}\text{ m}^2}$$

These calculations are indicated for each traverse and at each level on the traverses in Tables II-8 and II-10. In that the subtidal samples are mostly trawls or dredges, they are combined; the grab samples seldom caught larger animals. There seems to be little difference in the number of taxa from region to region. The Orcas Island traverses have about the same number of species as the Guemes traverses, while the small-island traverses are slightly less rich and the Lummi Island traverses rather poor in numbers of species. On the other hand, the Orcas Island traverses seem to have more standing crop than the others — followed by the small island and Guemes — and Lummi Island has the poorest.

Figure II-18 presents the megafaunal diversity data graphically. In most cases, a diversity index gives a better evaluation of the makeup of a community than does population number or species number alone. Figure II-19 illustrates standing crops of all organisms taken from the $1/2\text{-m}^2$ quadrat samples. Differences between the various intertidal zones are evident in both of these sets of graphs. Note in Figure II-19 that the consistently lowest

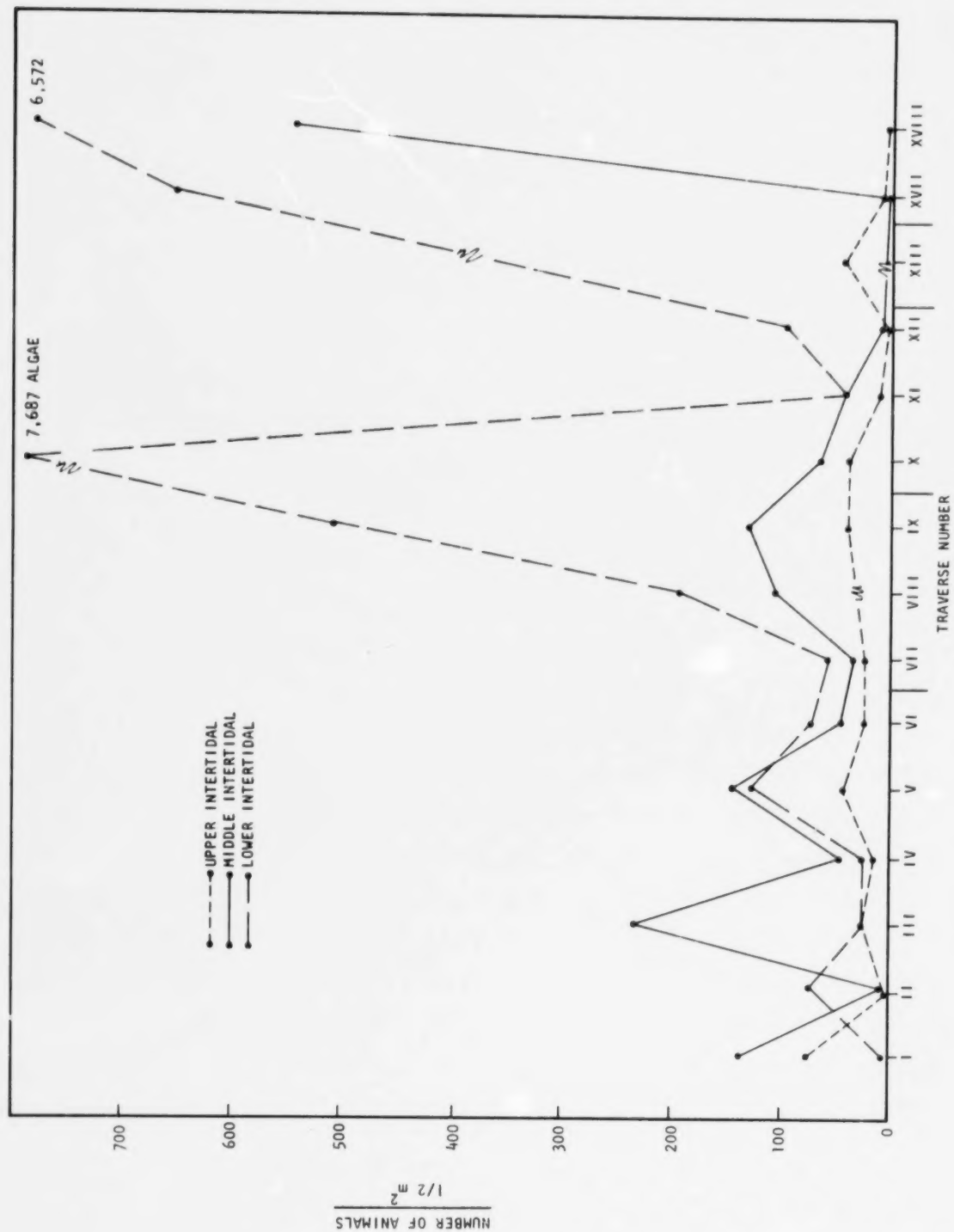


Figure II-19. Faunal Counts from Shore Quadrats $\frac{1}{2}m^2$



populations are found in the upper intertidal zone, while the largest populations (often two orders of magnitude greater) are found in the lower intertidal zone. Lowest diversity indices characterize the upper intertidal zones, where the environment is harshest for marine animals. Data from the middle intertidal zone fluctuate widely from traverse to traverse and from area to area.

Lower intertidal indices are the most consistent between areas and fluctuate the least, except on the west end of Guemes and the west side of Lumm Island. Both of these high diversity indices are misleading since only one or two organisms were taken in that zone and each was a different species. A ratio of 1:1 or 2:2 produces a diversity index of 1.00, the highest diversity possible. Subtidal megafaunal diversity also fluctuates widely but, in general, is higher than that of the intertidal zones. This observation agrees well with the ecological principle that stability of the environment is directly proportional to diversity. Furthermore, the more stable and predictable the environment, the higher the diversity (Slobodkin and Sanders, 1969; Parker, 1971).

It goes without saying that the subtidal is a more stable and predictable environment than the intertidal region. In general, lowest diversity figures seem to be found in the small-island area (Huckleberry, Saddlebag, and Hat Islands), with overall lowest figures for the Saddlebag Island traverse (Figure II-18). This is most revealing inasmuch as this traverse was characterized by the largest amount of oil seeping from the sediment and from under the rocks. The amounts of oil at this traverse were surprisingly large considering the length of time which had elapsed since the spill. Traverse III on Guemes also had low diversity indices for all intertidal levels; here, oil was much in evidence in the intertidal area.

Although the presence of oil in the substrate and the low diversity appear to show close correlation, it would be dangerous to state that this might be the only factor to cause low diversity. Since salinity is con-



sidered one of the major environmental factors influencing marine organisms, it would be surprising indeed if there were not some correlation between salinity and diversity. Although interstitial water samples could not be collected at every locality (some beaches were dry), the majority of intertidal zones provided sufficient water for salinity analyses. These analyses are given in Table II-9 and graphed in Figure II-20.

Salinity values throughout most of the San Juan Island region are within the normal Pacific Coast marine range, i. e., $20^{\circ}/\text{oo}$ to $33^{\circ}/\text{oo}$. The plots of salinity (Figure II-20) reveal some interesting facts, the most important being that very low values occur occasionally in the intertidal region. These low values were from areas where water could be seen seeping from above the beach and must be a result of groundwater seepage. For example, very low salinity values were obtained from the middle intertidal zone of traverse III on Guemes Island and the upper intertidal zone of traverse X on Orcas Island: both locations were found to have the lowest diversities of the traverses studied (Figure II-18). The fact that low diversity on Guemes was coincident with large amounts of oil and low salinity somewhat decreases the possibility that ecological damage was sustained by oil alone.

2) Meiofauna

Among the most valuable biological data obtained from this study are those pertaining to the smaller organisms — the meiofaunal invertebrates and the microorganisms, principally bacteria. No comparative data exist for these trophic (feeding) levels in the San Juan Island region. Data of the same sort have been collected using similar methods from Woods Hole, Massachusetts (Parker et al, 1971), a region of similar climate, and from the Texas coast (Parker et al, 1969; Culpepper et al, 1969; Blanton et al, 1970; and Parker and Blanton, 1970). It is possible, therefore, to make objective comparisons between areas and within the same region. The only drawback to using these data in their present form is that counts and kinds of meiofaunal animals and bacteria cannot be taken to the species level.



Inasmuch as so little work has been done on these small but important pollution indicators, most of the organisms have not been described to species; this is particularly true of the San Juan Island region.

Many of the meiofaunal comparisons, using both standing crops and diversity indices, are made on the basis of the major groupings (higher taxa) only. This may seem highly inaccurate from the standpoint of taxonomy, since a major taxon, such as Nematoda, may contain many species at one station and only one or two at another. Inasmuch as the recognition of taxonomic units at the species level for these meiofaunal groups is highly subjective and none of the sorters are recognized specialists in all groups, a set of taxa levels easily recognized by all of our sorters was chosen. All of these are sought for in every sample, so there is a common level of taxonomic affinity used in all samples. We feel reasonably sure that all sorters have sorted out all groups accurately and without taxonomic bias; for this reason, valid comparisons of diversity based on number of taxa per sample are possible with both our quadrat diversity and Van Veen diversity calculations given in Table II-10.

Counts of these major taxonomic groups for each sample analyzed so far are given in Appendix C. These counts include the smaller organisms from both Van Veen grab samples and the random and quadrat samples. Total organism counts for only the $1/25\text{-m}^2$ Van Veen grab samples are given in Table II-10. The Van Veen counts are quite typical of Boreal intertidal and just subtidal communities ranging from about 50 to 29,000 per $1/25\text{ m}^2$. Similar counts were obtained from the tidal channels of Hadley Harbor, Woods Hole (Parker, 1971). They are considerably higher than the counts obtained from most of the subtidal habitats of the northern Gulf Coast.

Plots of diversity indices for intertidal stations derived from $1/25\text{-m}^2$ Van Veen grab samples are shown in Figure II-21. In all cases,

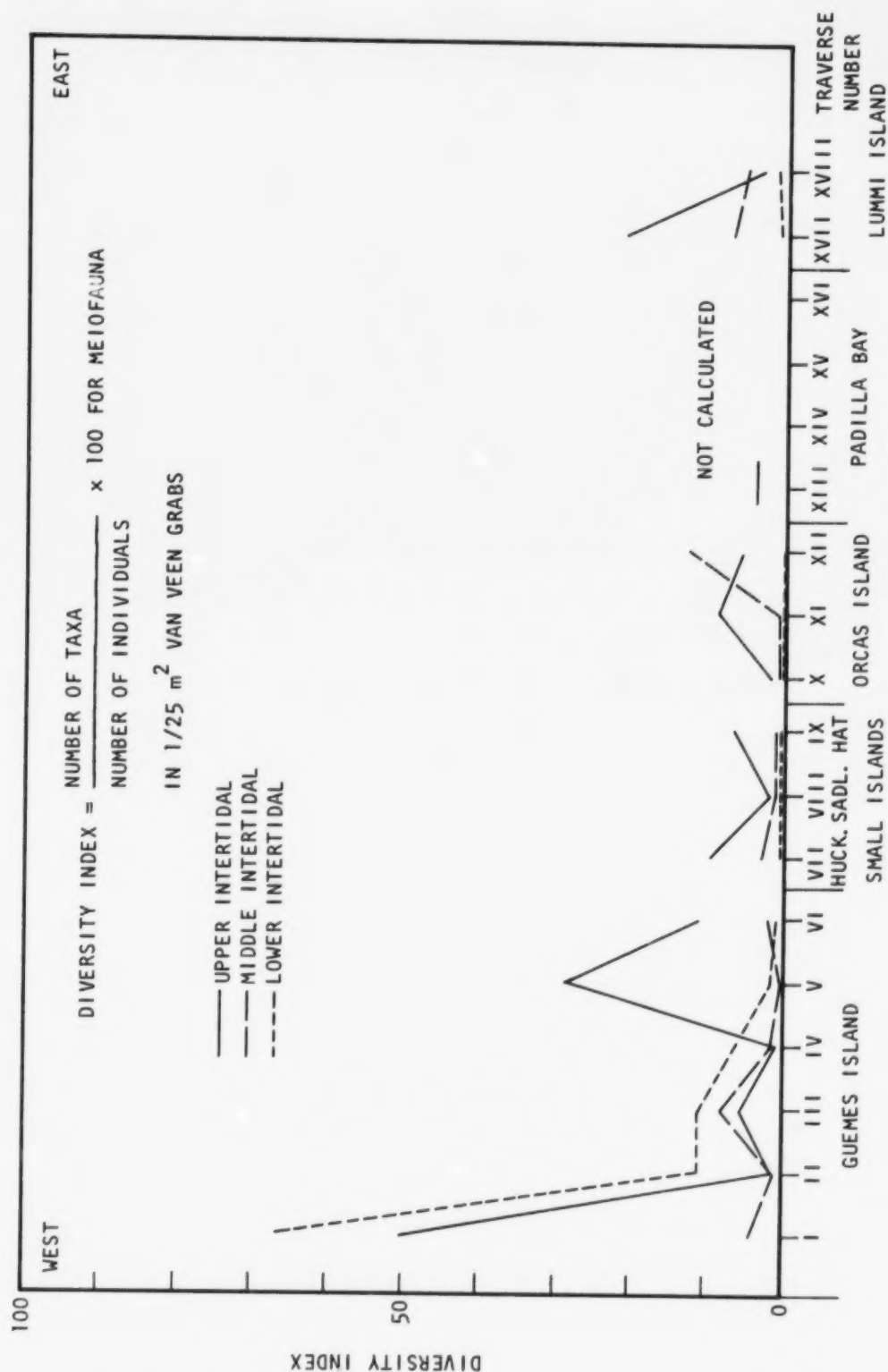


Figure II-21. Plots of Meiofaunal (200- to 750-μ) Diversity Indices from 1/25-m² Van Veen Grab Sample for Intertidal Zones Only. None were taken in Padilla Bay. Note low figures at oil-laden traverses II, IV, V, and VIII



diversity for meiofauna was calculated by

$$\text{diversity index} = \frac{\text{number of taxa}}{\text{number of individuals}} \times 100$$

Lowest counts are typical of the upper intertidal on most of the traverses, lowest counts per traverse being at Guemes Island, III and V, and Lummi Island, XVII and XVIII. The low values can be attributed both to salinity and oil on Guemes and to natural conditions and possibly oil on Lummi. Certainly, evidence for either salinity or oil as a disrupting influence is not conclusive. Rather surprising are the high values for Saddlebag Island (VIII), the traverse with the most visible oil. The control area, Orcas Island at Deer Point, provided no clear comparative data. The highest value, however, was found at Orcas traverse XI.

Diversity indices for subtidal Van Veen samples are shown in Figure II-26 and are compared with lower intertidal indices inasmuch as all three levels are submerged most of the time. Diversity for these levels is frequently highest in the lower intertidal — primarily because it is a gravel-to-cobble bottom, which provides many niches for small invertebrates and fish. Consistently lowest figures were obtained from data taken in Padilla Bay (richest in overall populations). This is a result of taking tremendous numbers of nematodes which, by their numerical dominance, mask the other taxa. Low figures also characterize most of the Guemes subtidal samples, suggesting possible ecosystem disturbance at those levels. This is substantiated by observations of bubbles of oil rising from the bottom in depths to 3 or 4 m.

Plankton is usually not considered in the same light as benthos but, in the case of samples taken for plankton estimates in Padilla Bay, there appears to be little difference between benthic and plankton animal composition (Table II-11). Apparently, depths were so shallow that the net skimmed the surface sediments, because between 50 and 70 percent of the zooplankton

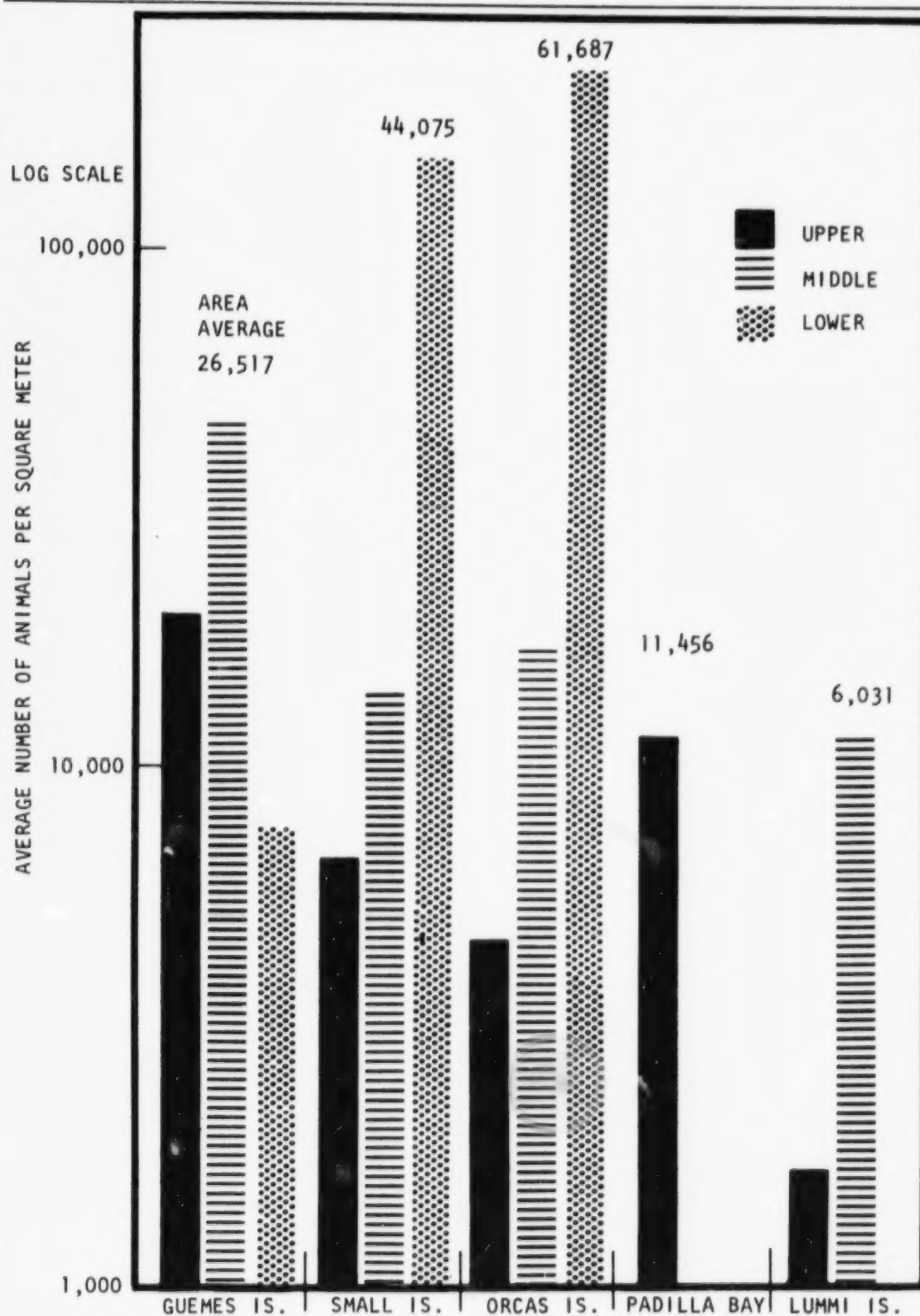


Figure II-22. Comparisons by Intertidal Zones of Average Meiofaunal Counts/m² for All Areas. Note similarity between values for control area, small islands, and Lummi Island and striking differences for the high-impact Guermes area



taxa taken are benthic inhabitants. It is significant that there are large numbers of larval forms, suggesting that the spill had not interrupted normal development for many forms — at least not in Padilla Bay. Approximately 20 percent of the animals in the tows are larval forms.

One can look at these same data also as averages by sampling area and as counts/ m^2 , the standard unit for most benthic biologists. Since the meiofaunal counts are most complete for the intertidal zone, only those data will be discussed. All grab sample counts were multiplied by 25 to get the m^2 figure. These were averaged by intertidal zone for each area (Guemes, the small islands, Orcas Island, Padilla Bay, and Lummi Island) and plotted on a log scale, as shown in Figure II-22. Average animals/ m^2 were also calculated for each area as a whole and are included in the same illustration.

Faunal population relationships between different regions now seem to be somewhat clearer. The largest average populations (standing crops) were found in the control area on Orcas Island, and this is as it should be. The second largest populations were found in the small islands, two of which are thought to have escaped the oil spill. Guemes Island counts are half the average of the small-island counts and a little more than a third of the counts of the control traverses. Both Padilla Bay and Lummi Island averages are low.

Inspection of Figure II-22 reveals another interesting observation. At the lower intertidal level, the average faunal counts of the Guemes traverses are only a third of the count averages of the small-island traverses and the Orcas control traverses. This would suggest that some damage to the normal community structure has been sustained on Guemes Island. All three intertidal zones in the small-island and Orcas control traverses have very similar population structures, but the Guemes traverses are different at all three intertidal levels. These figures have been reworked in another fashion in Table II-12 to give the deviation from the mean of each intertidal level for each sampling area. Average m^2 population counts are lowest at .

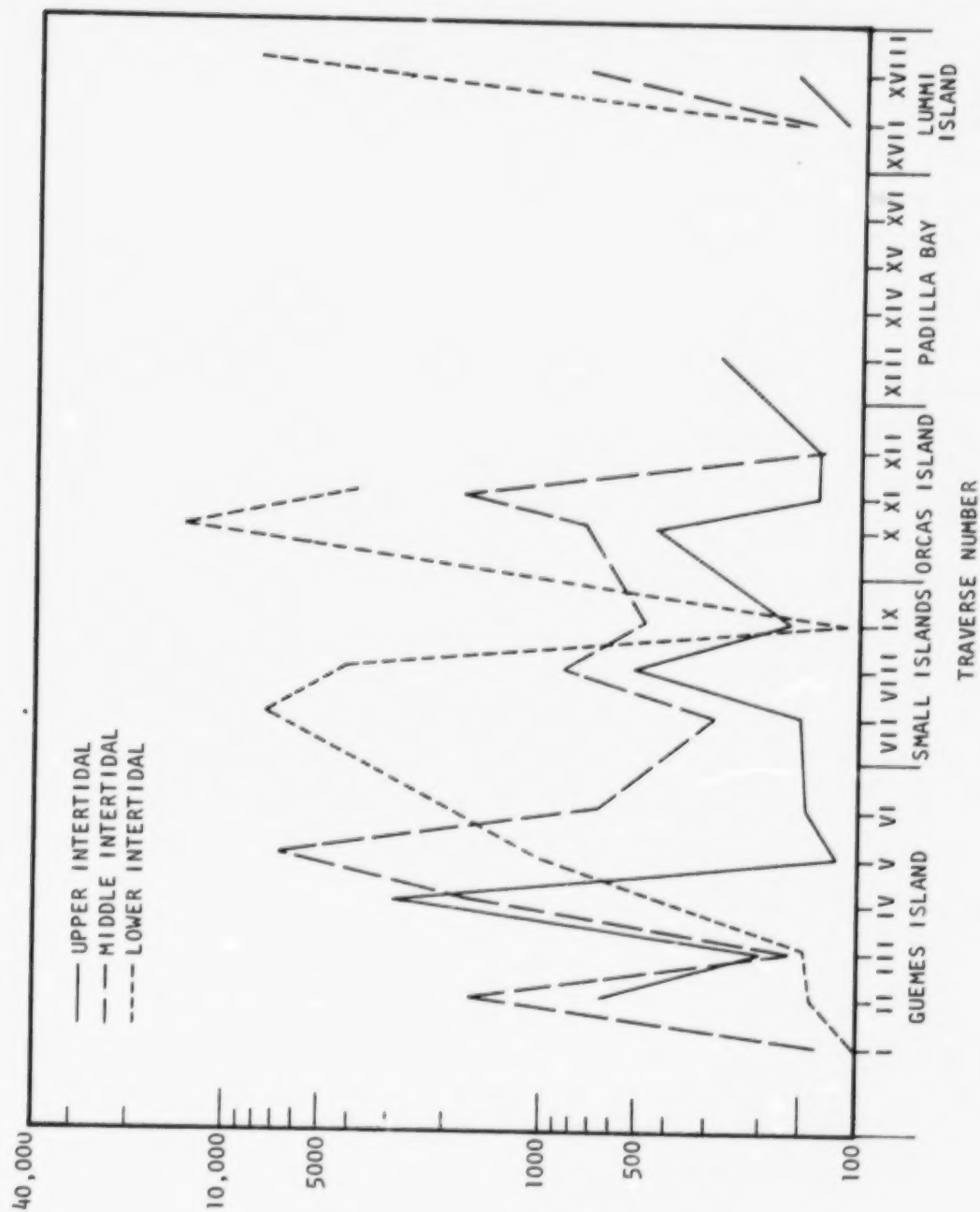


Figure II-23. Log-Scale Plots of Total Counts of Meiofaunal-Sized Organisms from 1/25-m² Grab Samples as Compared by Intertidal Zone, Traverses, and Areas



the upper intertidal, intermediate at the middle intertidal, and very high (over 122,000/m²) in the lower intertidal zones. This progressive increase in animal numbers from the top of the intertidal zone to the bottom was expected.

Observing the deviations from the average or mean by areas is of somewhat more interest. Within the upper intertidal zone, a progression from lowest numbers to highest numbers is shown from Lummi Island (with very low numbers) to Guemes with relatively high numbers. This increase makes sense, when one looks at the figures for Orcas Island traverses, which are almost as low as those for Lummi Island. The reasons are not immediately evident, but it is suggested that the upper intertidal beaches of both Lummi and Orcas are essentially barren because there is no interstitial water present (or at least the lack of retention of water) due to high porosity. The upper intertidal beach of Guemes is rather wet and apparently can sustain larger numbers of animals. At the middle intertidal level, the situation is much like that of the upper intertidal, with Lummi Island below normal and Guemes above and the small islands intermediate (Table II-11). A major change in these relationships exists at the lower intertidal, where Guemes Island traverse counts are below average and Orcas Island counts are above average. Since a possibly disturbed area is being compared numerically with a control area, it would appear that the ecosystem has been disrupted at the lower intertidal zone of Guemes Island. As mentioned previously, it is at this level that most of the residual oil was observed seeping into the water.

A final check for ecosystem disturbance based on meiofaunal counts is the calculation of diversity indices using the sample counts vs the number of major taxa in each sample. The results of this manipulation of data from the 1/25-m² grab samples are shown in Tables II-9 and II-12 and in Figures II-23 and II-25.

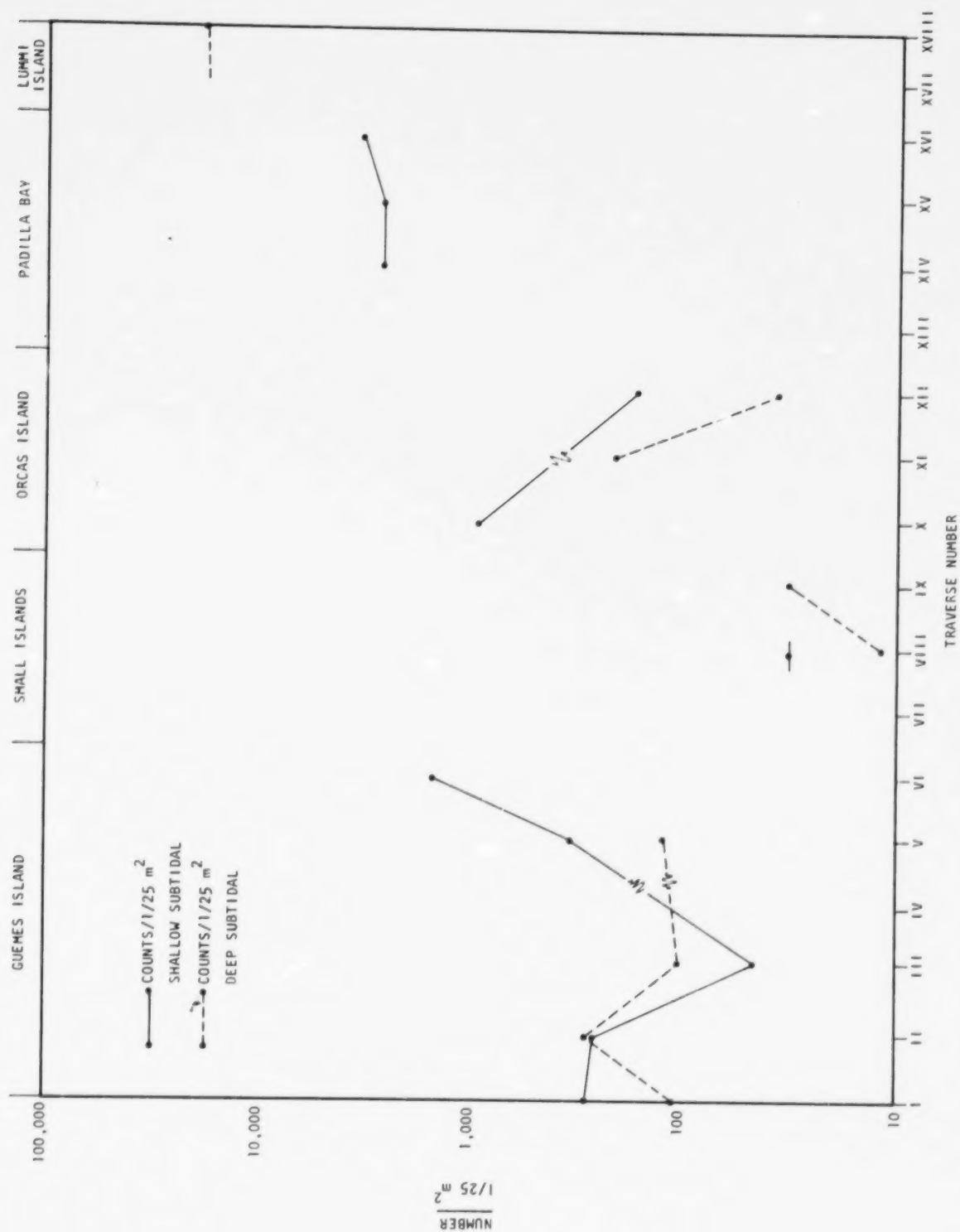


Figure II-24. Total Counts of Animals for 1/25-m² Van Veen Samples, Subtidal Depths

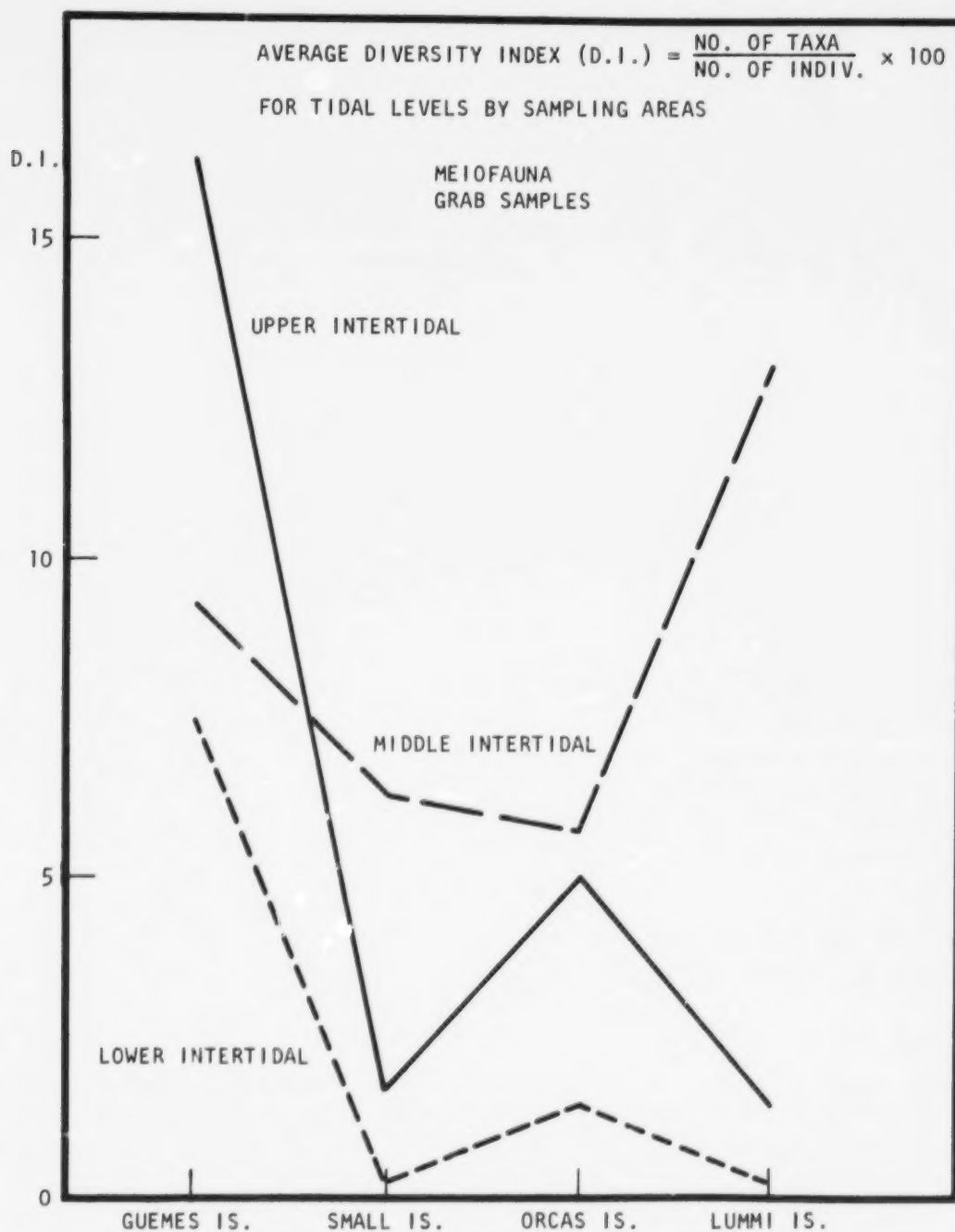


Figure II-25. Average Diversity Indices Based on Meiofaunal Counts and Major Taxa Identifications for Four Major Areas by Intertidal Zones. Note that, on a gross evaluation, diversity indices separate widely for each zone

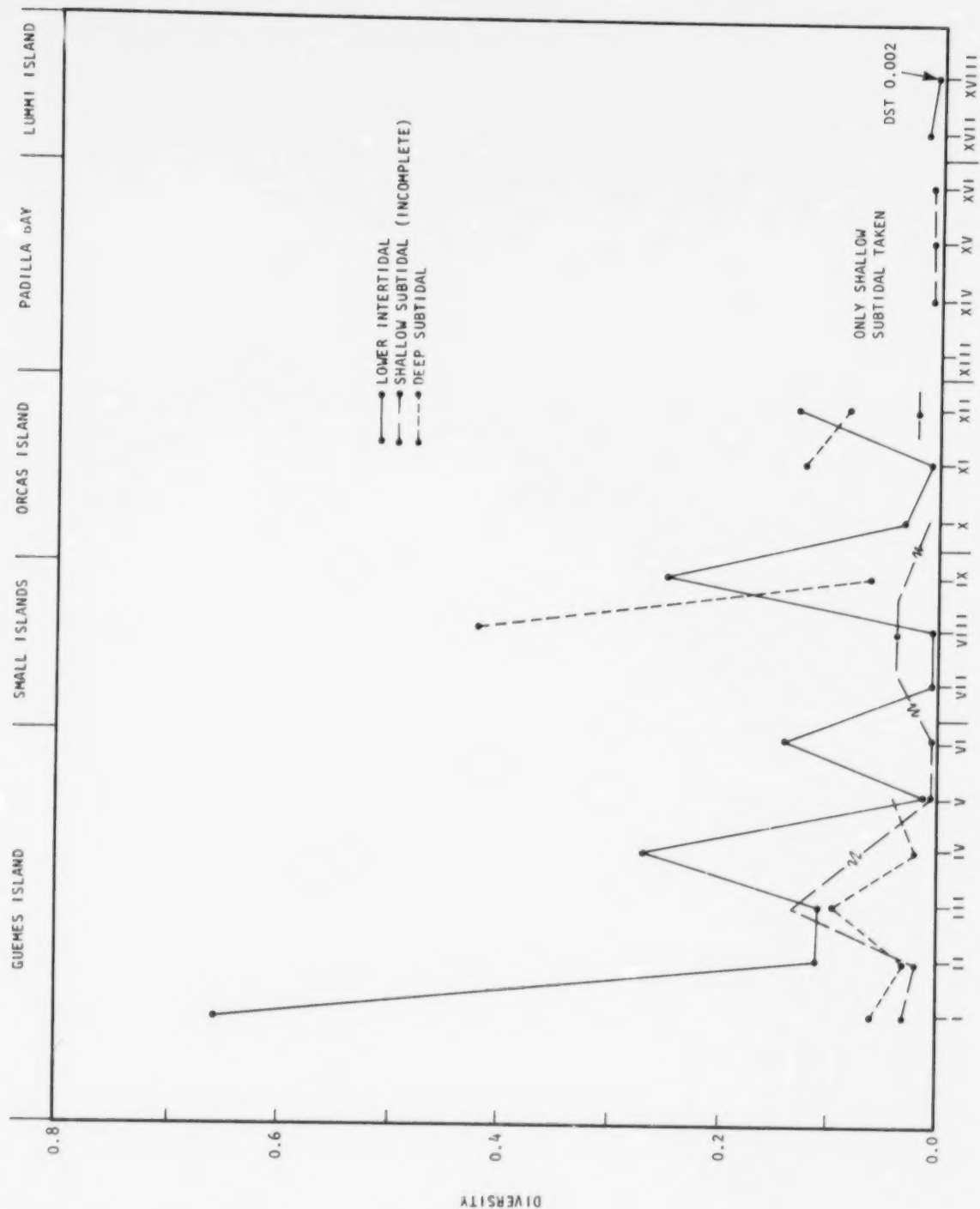


Figure II-26. Comparisons between Diversity $\left(\frac{\text{No. of Taxia}}{\text{No. of Individuals}} \right)$ within 1/25-m² Van Veen Samples at Lower Intertidal to Deep Subtidal Depths



From an examination of Figures II-25 and II-26, the following observations are made:

- Upper intertidal counts are relatively uniform and low except for traverse IV on Guemes Island, a zone where sediments differed from the rest of Guemes UIT and probably where the sediment type is the controlling factor for population size.
- Lower intertidal counts are significantly different between Guemes and the control area on Orcas Island and Huckleberry Island. LIT zones on these latter traverses produced very large populations (on the order of 11,000 to 14,000 animals per $1/25 \text{ m}^2$), the highest encountered in any of our related studies on other coasts. On the other hand, counts at Guemes traverses I and V (high-impact areas) and XVII on Lummi Island (a possible oil-impact area) were very low. On the surface, it would appear that these counts indicate ecological damage in the LIT at these locations.
- Deep subtidal counts (Figure II-25) are uniformly low and are very similar in magnitude to those of the UIT at each location, suggesting that the same relationships between environmental stability and diversity and abundance hold true for both onshore and offshore areas within the same traverses.
- The three shallow subtidal samples taken in Padilla Bay produced extremely high faunal counts of approximately 5000 animals per $1/25 \text{ m}^2$. No ecological damage was reported or observed in the sampled portions of this bay.

The graphs of these indices by individual traverse and by regions (Figure II-23) again show that the traverses with marked amounts of visible oil have sustained some sort of environmental stress. The lowest diversity indices are found at traverses II and IV on Guemes as well as on Sadlebag Island traverse VIII. These low diversities suggest that oil and low diversity go hand in hand. Unfortunately, the Orcas (control) traverses are not much richer and, using this index, Guemes traverses I and V have inordinately high meiofaunal diversities. Lummi Island traverses are marked by generally higher diversities than those of either the small islands or Orcas.



Plots of average diversity indices for intertidal zones by major areas (Figure II-25) show rather anomalous results. Highest average diversities are found in the upper intertidal, intermediate in the middle intertidal, and lowest in the lower intertidal. What is more surprising is that Guemes Island has the highest diversity indices (a numerical artifact) for two of the three intertidal zones and is higher than either the small-island and Orcas traverses at the third or middle intertidal zone. These reversed figures from previous manipulations result from the fact that very large numbers of animals with no change in number of species create low diversity indices.

From the discussion of meiofauna abundances and diversity as they pertain to this study, it can be seen that this kind of data constitutes a useful tool for ecological damage assessment when little baseline data are available. Obviously, meiofaunal data from the spill area alone would not have this value placed on it without comparative data from control or other undamaged areas. It is suspected that meiofaunal abundances and variety are perhaps more useful than similar data for the larger organisms because their tissues are more directly in contact with their surrounding environment; i. e., their skin is thinner with fewer cell layers and thus more sensitive to changes in water quality. The majority of these forms are infaunal and are more likely to remain in place when a disturbance occurs. Larger animals can often escape both the initial disturbance and avoid areas of lingering effects.

3) Microflora (Bacteria)

Table II-14 is a complete list of all microbial data and observed environmental conditions at the times of collection. Comparisons between bacterial diversity, direct cell counts, and luminescence biometer counts for all transects are given in Figures II-27 through II-30.

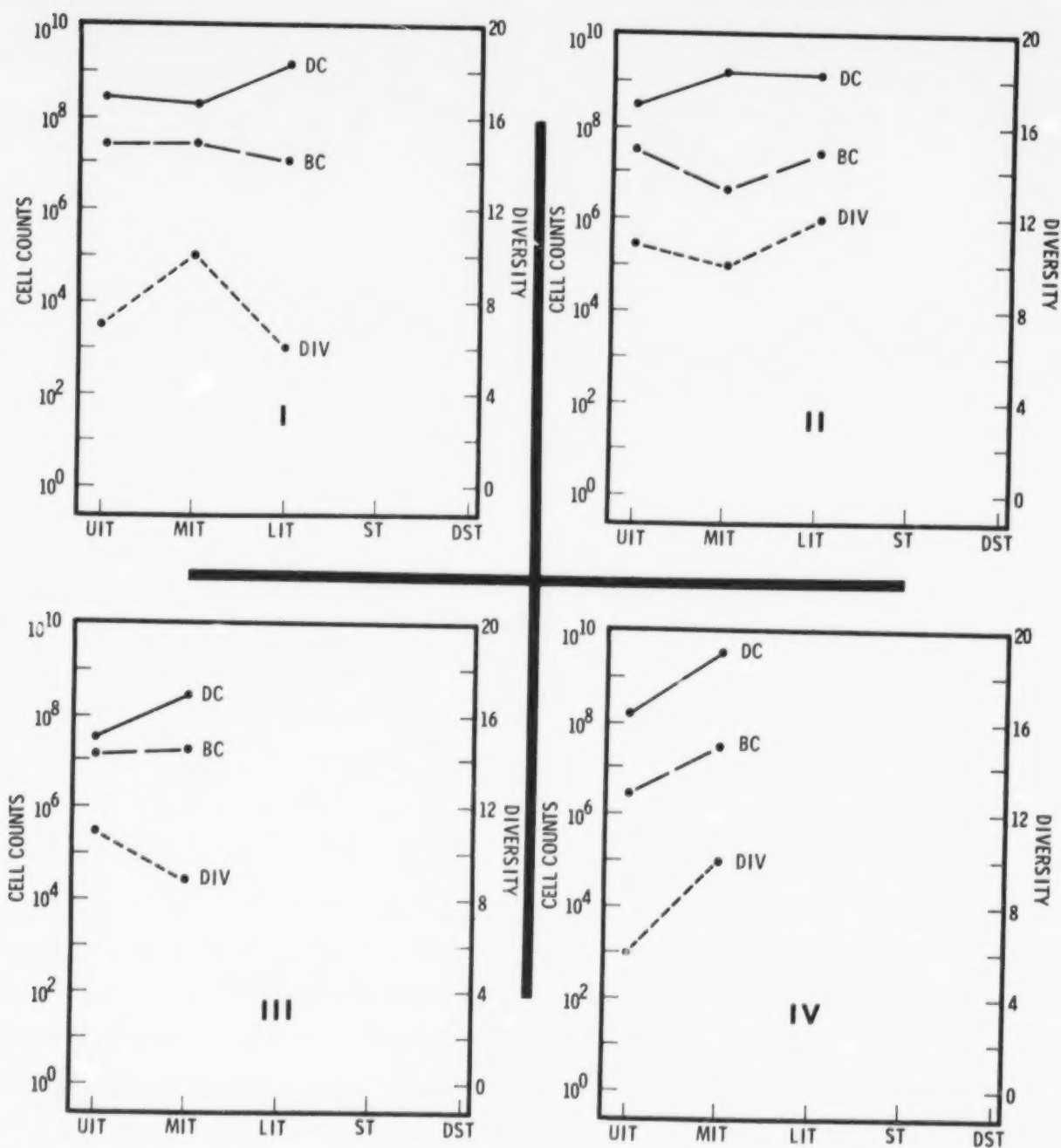


Figure II-27. Shore Transects I through IV: Plot of Bacterial Cell Counts Derived from Direct Microscopic Cell Counting (DC) and Luminescence Biometer (BC) as Compared with Number of Cell Types or Diversity (DIV)

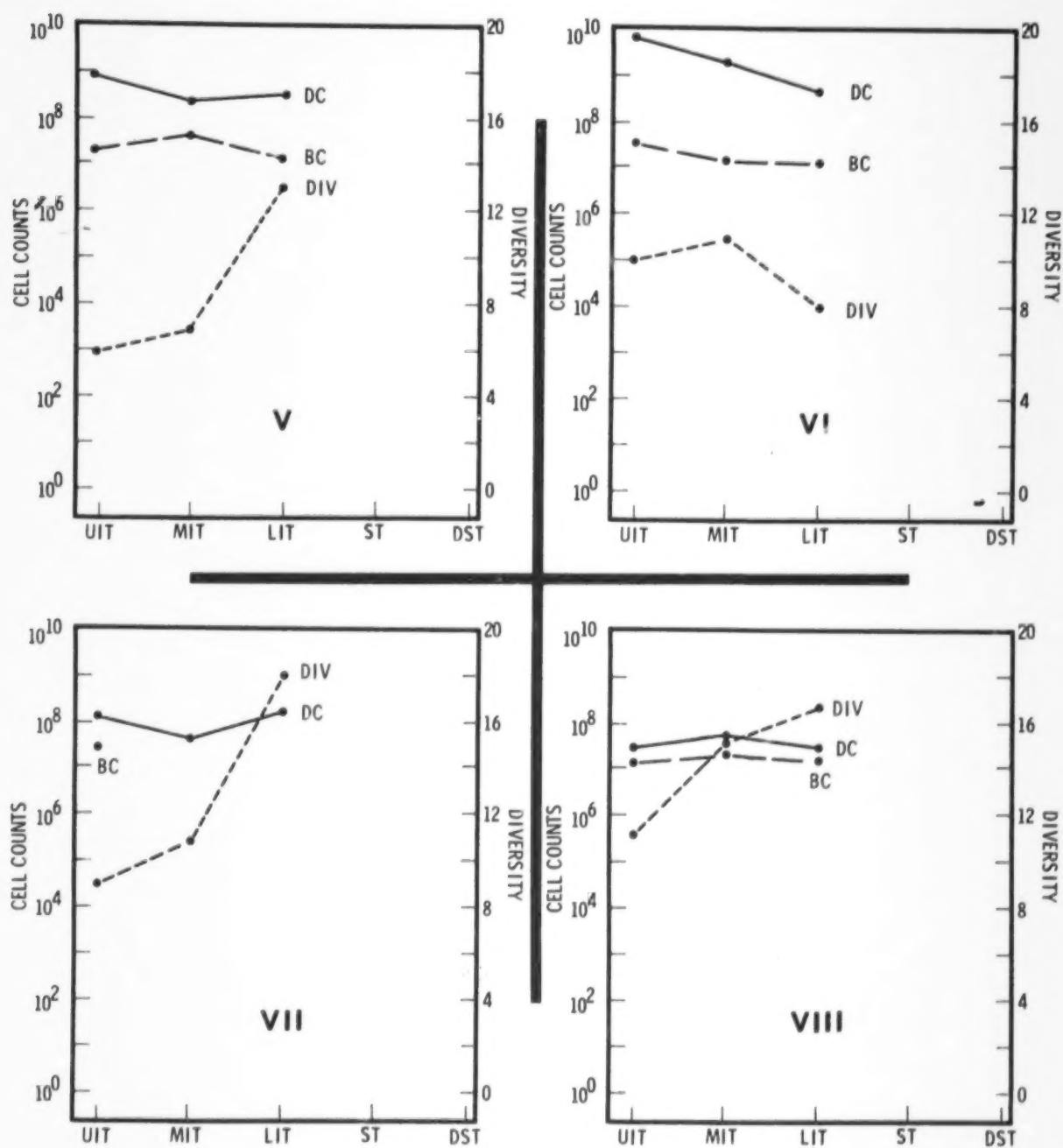


Figure II-28. Shore Transects V through VIII: Plot of Bacterial Cell Counts Derived from Direct Microscopic Cell Counting (DC) and Luminescence Biometer (BC) as Compared with Number of Cell Types or Diversity (DIV)

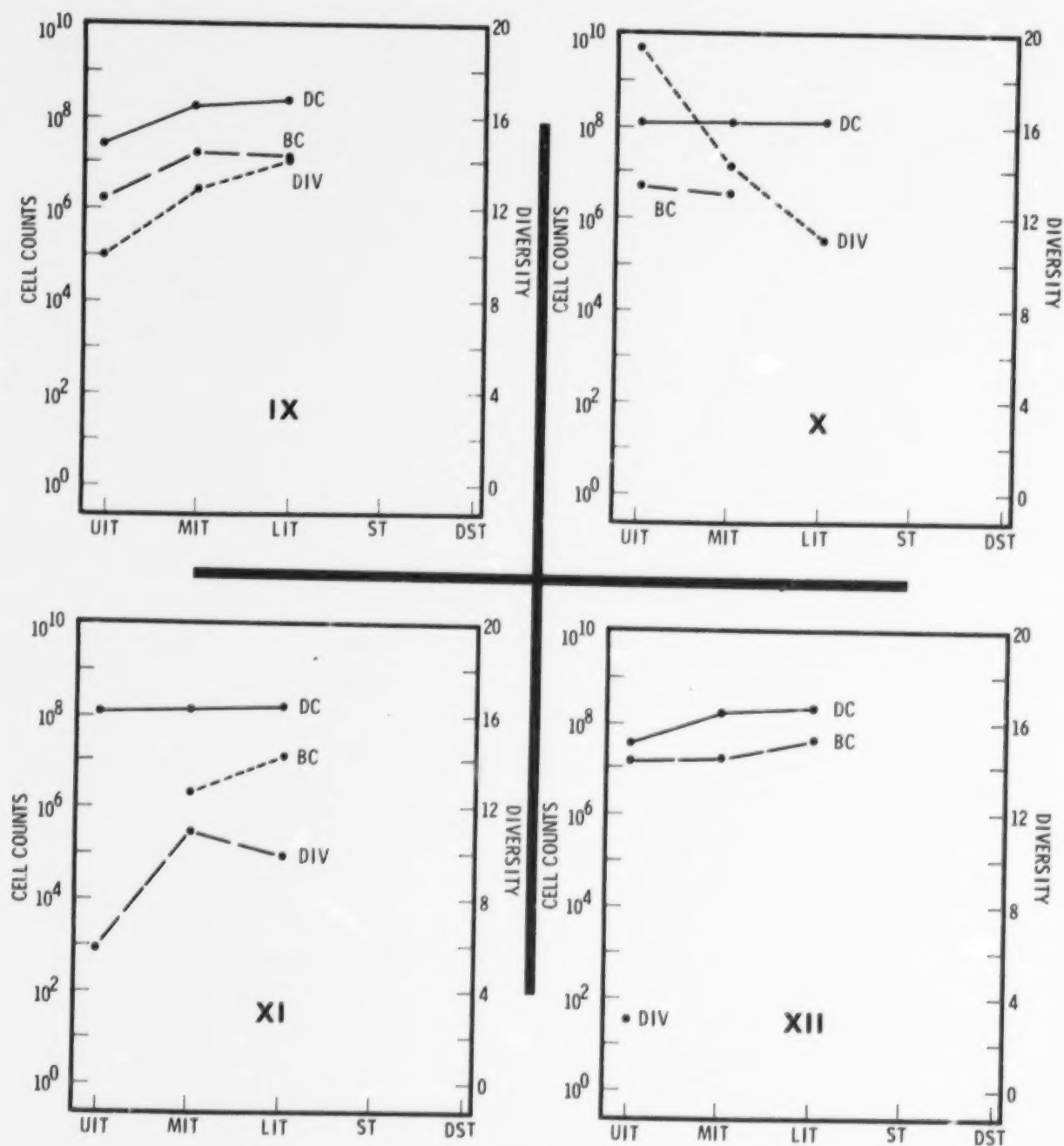


Figure II-29. Shore Transects IX through XII: Plot of Bacterial Cell Counts Derived from Direct Microscopic Cell Counting (DC) and Luminescence Biometer (BC) as Compared with Number of Cell Types or Diversity (DIV)

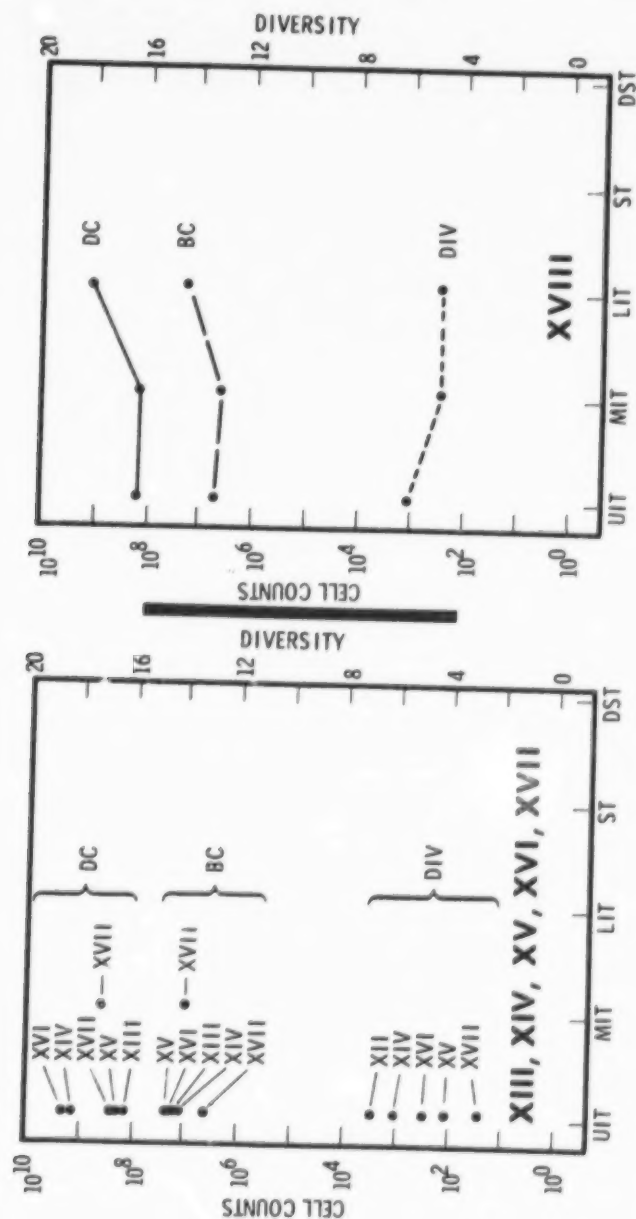


Figure II-30. Traverses XIII through XVIII: Plot of Bacterial Cell Counts Derived from Direct Microscopic Cell Counting (DC) and Luminescence Biometer (BC) as Compared with Number of Cell Types or Diversity (DIV)



Generally speaking, luminescence biometer counts are usually within the same order of magnitude as direct cell counts and are usually slightly higher than direct counts because of increased precision. It is considered significant, therefore, that most of the samples processed in this project do not follow the normal convention.

Direct counts were universally higher in these samples than the biometer counts, indicating that a sizable fraction of the cells counted by direct methods were dormant or dead. The greatest discrepancies were found in shore traverses VII, X, and XI; lesser discrepancies were noted in the traverses on Guemes, where oil seepage was observed (Table II-14). Direct cell counts of 7.5×10^7 and 2.5×10^8 cells/cc were made on samples from shore traverse VII, middle intertidal (MIT) and lower intertidal (LIT). These counts are within the normal range expected for these locations. However, luminescence biometer counts revealed that very few of these organisms were alive (as indicated by Adenosine Triphosphate [ATP] measurements). A petroleum odor was not detected in the field at station VII, MIT, although considerable oil was extracted from the sediment during washing for meiofauna. On the other hand, an oily odor was detected in the field at station VII, LIT; likewise, considerable oil was found in the sediment sample when washed. These data indicate that the oil may be toxic to those bacteria and that instead of consuming the oil they may have been killed by it.

Similar discrepancies were noted at station X, LIT, in the Orcas Island control area in which a direct count of 1×10^8 was made; the biometer count was negligible. Salinity data from the interstitial waters, it should be noted, show groundwater seepage in this area and salt water flushed from the sediments at low tide (Figure II-20); for this reason, it is believed that many marine bacteria residing in that habitat during high tides would be disseminated by the fresh-water influx — a natural stress on a marine ecosystem. No data are available at this time to explain the low bacterial populations within the sediments at station XI, upper intertidal (UIT). Populations of meiofauna are also very low ($1500/m^2$) within this station, suggesting another stress condition.



Certain other information may be inferred from these data. For example, the bacteria from all transects appear to be in an increasing death phase in the intertidal zone during low tidal periods. Populations should be replenished during high tides and would again die during the next low tide. This could account for the difference between direct and biometer counts. Tidal ebbs and flows, coupled with low temperatures and the fact that considerable oil was present in many sediment samples from the high-impact area (south shore of Guemes Island), indicate that degradation of oil by these organisms is negligible. In fact, data from traverse VII, MIT and LIT (Table II-14), indicate that oil can be toxic to marine bacteria.

3. Bioassays

Toxicity studies on the Texaco diesel-fuel sample provided by Washington State authorities were conducted using the materials and methods described in the following paragraphs.

a. Materials

A 25-l batch of artificial seawater was prepared, utilizing sea salts and distilled H_2O . The salinity was adjusted to 25 ‰ and the solution was agitated 18 hr (vigorously), utilizing five bubbler outputs and a silent giant compressor. Six glass (1-gal.) containers were prepared for the experiments as follows:

- They were thoroughly cleaned withalconox, a free-rinsing laboratory detergent.
- Each was thoroughly rinsed first with tap water and then with distilled water and then placed in an automatic glassware washer and rinsed with boiling hot water for one full cycle.
- Each was aerated with a frittered-glass bubbler attached to a silent giant air pump through a 5-unit metering manifold. The airflow through each bubbler was equalized through appropriate adjustments of the meter manifold.



The diesel fuel used in these toxicity studies was provided by Jerry Watson of Texas Instruments. The initial sample was procured by Washington State authorities. Aliquots of the actual oil spilled were not available, but communications with our suppliers indicate that this oil meets the same specifications as that spilled. We believe that toxicity tests utilizing this oil are directly applicable to estimated toxicity for the actual oil spill.

b. Methods

The first run was conducted to estimate the range of concentrations which might prove toxic to fish. It must be understood that data from the first run may be integrated into subsequent experiments, but their primary purpose was to determine toxic ranges quantitatively.

The following concentrations (by volume) were utilized in the first test series: 0.01 percent, 0.1 percent, 1 percent, 10 percent, and unaltered control = 0 percent.

Preparations of the concentrations included the following:

- 2000 cc of aliquots of the synthetic seawater were added to each glass container.
- Appropriate volumes of water were quantitatively removed and replaced with equal amounts of diesel fuel.
- The diesel fuel was dispersed into the receiving fluids, utilizing an ultrasonic cell-disrupter operating at 20 kHz and 125 w.
- Ultrasonic agitation of the fluids was continued until the oil was visibly dispersed throughout the fluids. Observations of the surface state of fluids were then made and the presence or absence of rainbows or sheens noted.

Procedures in the first qualitative run were identical to those for later toxicity runs (LC-50), the only variation being that, in the qualitative run, only one fish was utilized in each container whereas, in the actual LC-50 tests, four fish were placed in each container.

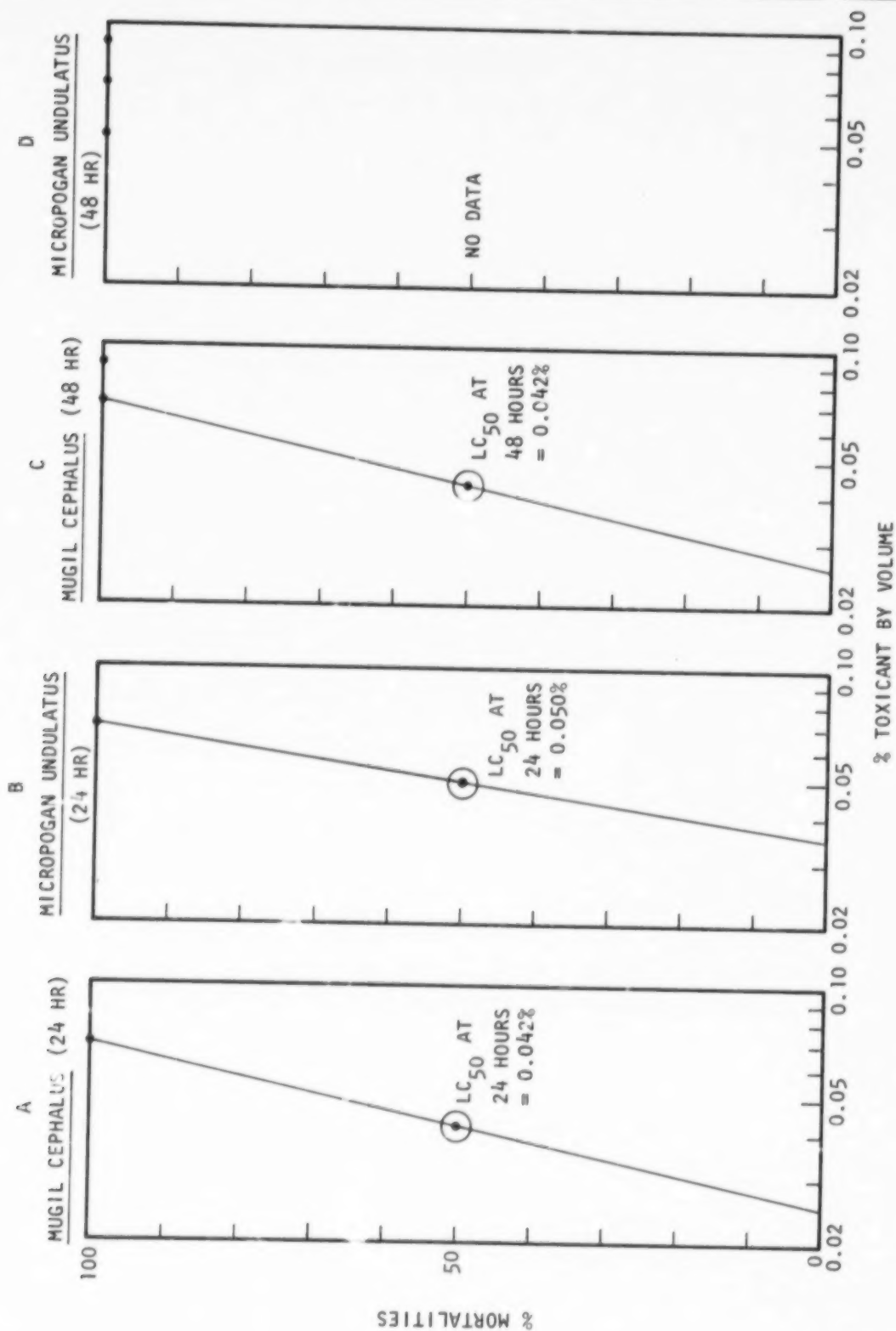


Figure II-31. Results of Toxicity Studies of No. 2 Diesel on *Mugil Cephalus* and *Micropogon Undulatus*



Water was pretreated as follows:

- Concentrations and dispersal were accomplished as previously indicated.
- The water was vigorously aerated for 10 min to assure O_2 saturation before test animals were placed in the containers. (This step was considered necessary because of heating produced during the sonication step for dispersing the oil; heating reduces oxygen solubility and the aeration step was used to return the water to its original O_2 concentration.)

The following was the procedure for introducing test specimens:

- Test fish (Mugil cephalus and Micropogon undulatus)^{*} were introduced into the containers and aeration was continued.
- The T0 (time zero) was noted for the introduction of each specimen.
- Behavioral responses for each specimen were observed and noted.
- T-terminal for each terminal (dead) specimen was noted.
- T-terminal notations with corresponding concentrations were noted and utilized in the computations of LC-50 (concentration of diesel fuel producing 50 percent mortality within 48 hr).
- Since the concentrations were added on a $\log_{10}$ basis, mortalities (48 hr) were plotted on semilog graph paper. The X axis (logarithmic) designates concentration; the Y axis (arithmetic) represents percent mortality in 48 hr.

c. Results

1) General

The data of the toxicity studies, shown in Figure II-31 (A, B, C, and D), indicate a wide variation between species in their sensitivity to this oil. Micropogon undulatus were killed in one-half the time (24 hr) required to kill Mugil cephalus. Our past experience with other toxicants



has demonstrated that Mugil cephalus usually exhibits intermediate toxic response to toxicants — and the LC-50 data cited here is based on the response of this species. There were no deaths among control fish.

2) Behavioral

All fish tended toward a "head up" posture when in the presence of 0.04 percent or higher concentrations of diesel fuel. This indicates some loss of integrity of the swim bladder. The specimens did not exhibit excessive excitation.

3) LC-50

The apparent LC-50 (mean lethal concentration) for species tested centers near 0.042 percent. This is the concentration which produced acute toxic effects (50 percent mortality/48 hr) in species studied. Acute toxicity is the concentration which, under laboratory conditions, kills many specimens after a short exposure to the toxicant. Chronic toxicity is usually considered to be the concentration which would damage the normal physiology of a specimen or kill the specimen after extended exposure. Chronic toxic levels are commonly extrapolated as 10 percent of the LC-50. Safe levels are usually taken to 1 percent of the LC-50. Using these values, one can extrapolate the following toxicity levels for the subject diesel for marine fish:

Acute toxic level	0.042 percent	by volume
Chronic toxic level	0.0042 percent	by volume
Upper safe level	0.00042 percent	by volume

It must be stressed, however, that laboratory analyses of toxicities may not correlate well with actual "field" toxicities because of dynamic environmental conditions. The LC-50 is a laboratory approximation of toxic characteristics of a substance; the substance per se may be more toxic or less toxic than indicated, depending on these other factors.



4. Sediment Analyses

Sediment analyses were not carried out by conventional settling tube-pipette methods, because the majority of samples collected had no fine material in them. They were all run through five standard sediment sieves giving size fractions of: > 4 mm, 4 to 2 mm, 2 to 1 mm, 1 to 0.5 mm, 0.5 to 0.25 mm, and < 0.25 mm. Percents by weight of each fraction are shown in Table II-15. Table II-16 presents the classification, designated by Pettijohn (1954), and the rock and sediment types derived from this classification for each sample.

Following are a few observations on sediment types for each of the intertidal zones. No samples were saved for sediment analysis in the subtidal zones, in that all of these sediment samples were used for hydrocarbon analyses.

- Upper Intertidal Zone

There is somewhat more silt and clay in the UIT of Guemes Island and more rock and gravel on the small islands. Sand is the most typical sediment type of the UIT of Lummi Island (Figure II-32).

- Middle Intertidal Zone

Fine sediments comprise a greater fraction on the small islands, and sand is predominant in this zone on Huckleberry Island and on the west side of Lummi Island. There is little difference in sediment type between the UIT and MIT on most of the traverses on Guemes and Orcas Islands (Figure II-33).

- Lower Intertidal Zone

Rock-sized material decreases significantly as a fraction in the areas sampled of the LIT except at traverse V on Guemes Island, on Hat Island, and at traverse XII on Orcas Island. Sand beaches characterize traverse III on Guemes Island, the Saddlebag Island traverse, traverse X on Orcas Island, and on the east side of Lummi Island (Figure II-34).

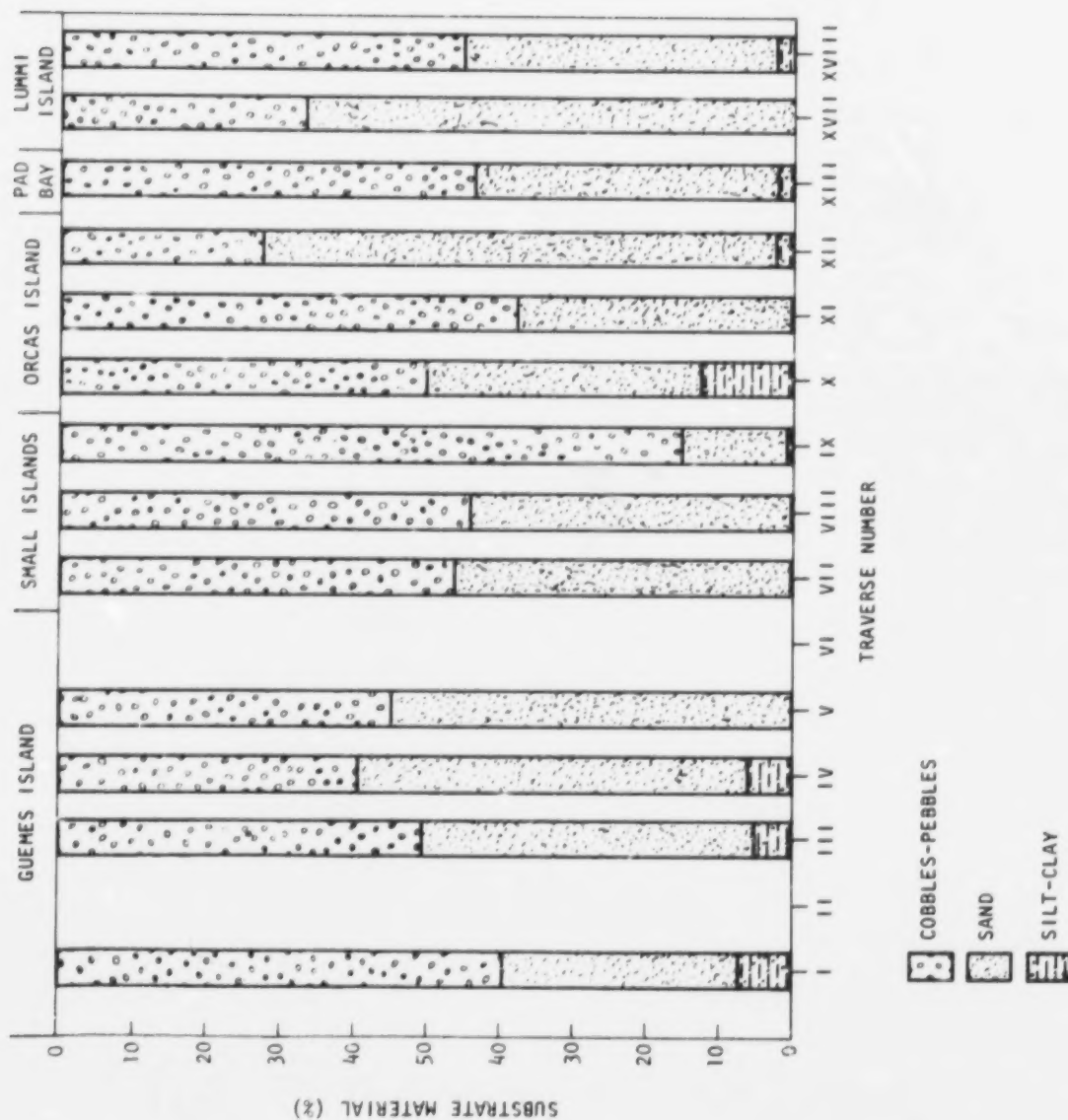


Figure II-32. Percent Cobble-Pebbles, Sand, and Silt-Clay, Upper Intertidal by Traverses

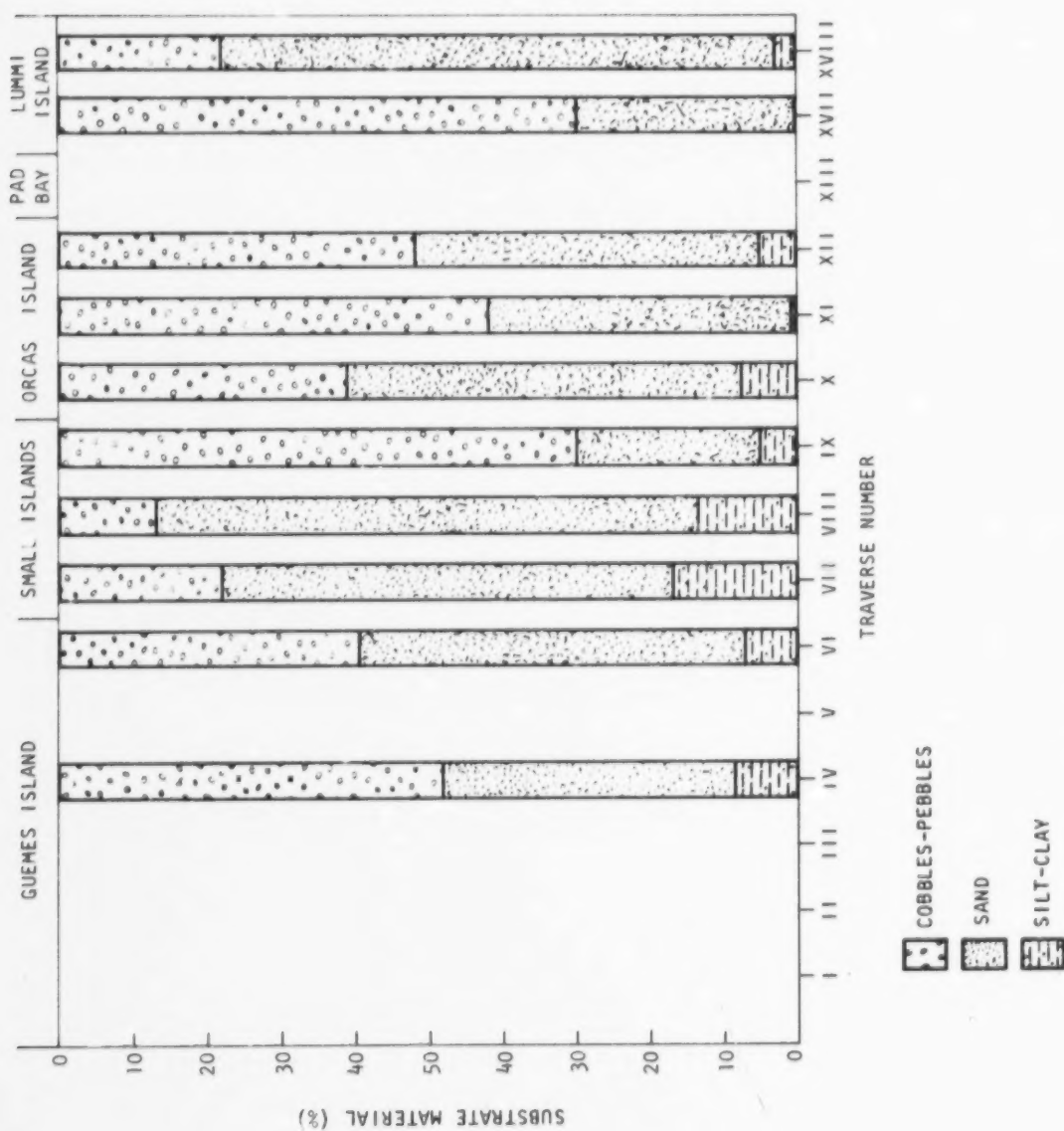


Figure II-33. Percent Cobbles-Pebbles, Sand, and Silt-Clay, Middle Intertidal by Traverses

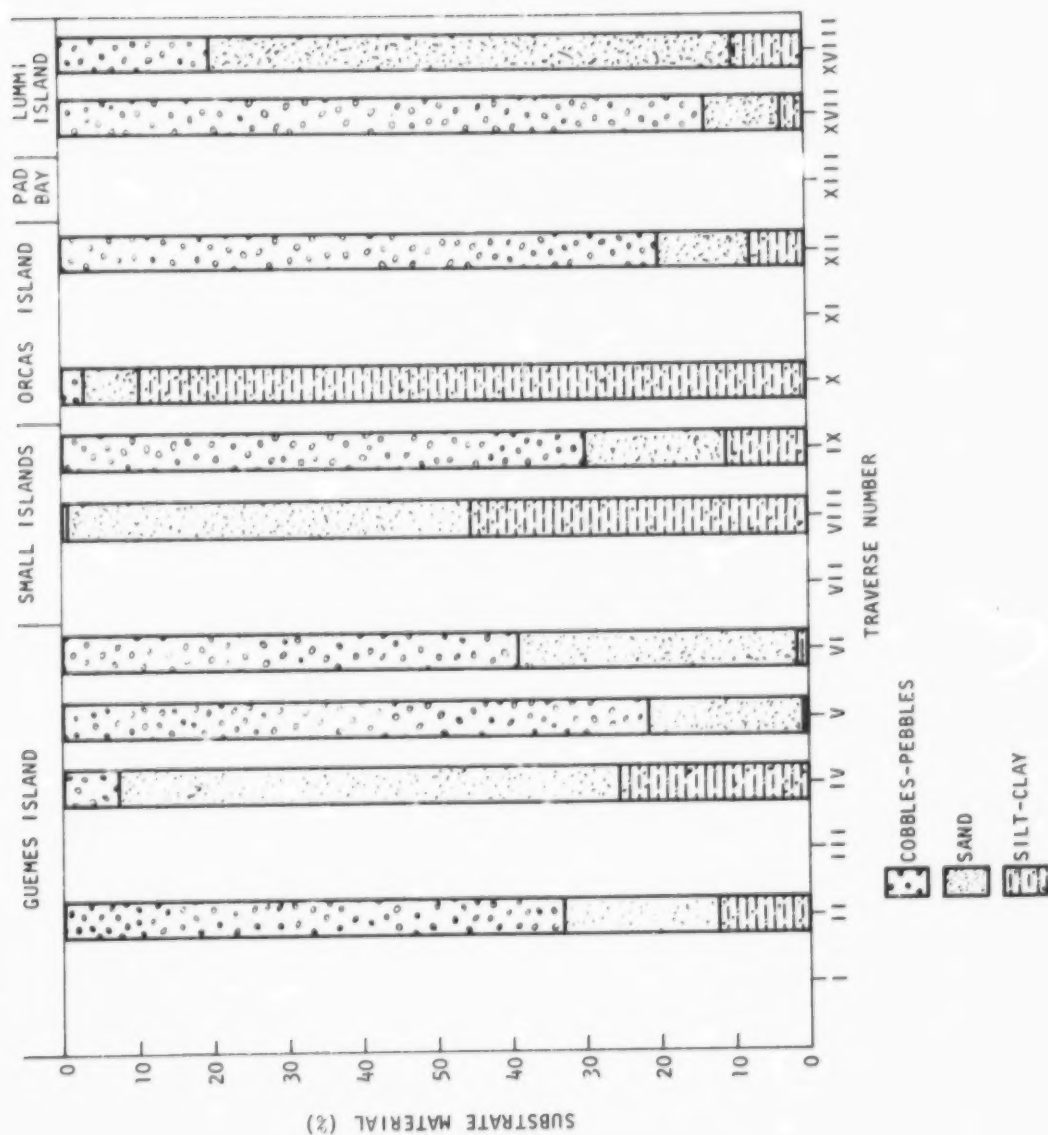


Figure II-34. Percent Cobbles-Pebbles, Sand, and Silt-Clay, Lower Intertidal by Traverses



east side (Figure I-2) to verify reports of environmental damage to crustacean (mysid and euphausid) populations in these coves.

There is considerable correlation between sediment size and faunal counts at the same stations. In upper and middle intertidal zones, large amounts of rock-sized material were associated with small numbers of animals. Poorly sorted, medium-sized sands in the lower levels of the beach produced the largest number of animals. It may be significant that hydrocarbons appeared to be more evident in the coarser material — which could also be the reason that animal populations are smaller on the rocky beaches.

5. Discussion

In attempting to assess damage to the marine environment from an occurrence such as the Anacortes oil spill, the usual methods of biological and hydrographical analysis do not suffice — especially when a spill occurs in an area of extremely strong currents and is in almost instantaneous touch with the shore. The previous discussion has pointed out the necessity for taking samples in control areas at the same time as in the affected areas.

It is perhaps safer to use comparisons in the same time frame rather than to attempt comparisons between old baselines and spill data. One of the reasons is the long time changes in biotic communities normally associated with long-term cyclic climatic changes; what may have been present 50 years ago may have naturally disappeared today. This is not to say that previous studies are not of considerable value if the same types of sampling have been carried out and the same systematic (taxonomic) confidence is inherent in both studies.

It is evident that biological variables alone are not sufficient to establish environmental damage. Although the resident time of waters in a particular location within the San Juan region is extremely short, one must still measure some of the standard oceanographic factors — particularly



salinity. The salinity data acquired in 1971 has proved to be of considerable value in explaining the low diversities and populations in one of the control traverses.

It is also observed that, within the area known to be affected by the oil spill, not all low populations and diversities can be definitely tied to the oil itself. There is the possibility that groundwater seepage (salinities below 10 ‰) could also have brought low diversities and populations in an area.

Biological damage is not always sustained at the time of a spill (or at least it is not always evident at the time of the spill); in most cases, the real damage may be inflicted upon future generations of the organisms. At almost any season, there are many invertebrate species in the process of reproducing or which have already reproduced and their larvae are going through developmental processes. Although the oil or hazardous chemicals may not kill the larger or adult animals, the larvae and juvenile forms may be killed, thus stopping replenishment of the population. Most of these organisms are at some time a part of the plankton, which ebbs and flows past the points at which they will eventually settle and grow to adulthood. Only during the seasons when these forms settle can true damage assessment to the environment be made; this is particularly true in the Anacortes spill and was borne out in the Buzzards Bay spill of diesel fuel 2 years ago. Sanders and his group (personal communication) state that it was only after a year of observations of larval settlement that the true impact of the Buzzards Bay spill was known. For this reasons, seasonal sampling trips of the same magnitude as described in this report should be carried out for at least a year. Only after a full year's data on these biotic communities have



been accumulated will the true effect of the oil on these organisms be evident. This study would also furnish an ideal Pacific Coast parallel to the Atlantic Coast study by Blumer and Sanders (personal communication).

6. Summary and Conclusions

A number of conclusions regarding possible damages to marine environments of the San Juan Islands area as a result of the oil spill in Anacortes, Washington, can be drawn from the data collected from 9 May to 13 May 1971. Evidence of environmental damage is both visual (oozing of oil from intertidal sediments) as revealed by photographs and verbal documentation and circumstantial as revealed by the detailed analysis of the faunal data collected during this study. Whether the environmental damage is of major magnitude, requiring a long period for recovery, is not known. Also, brief spills of a similar nature may have occurred before and gone unnoticed. Regardless of how much damage has been sustained and whether the damage is permanent, the following conclusions are now indicated:

- (1) Subtidal collections after the spill were not as rich as those made in 1958. There was a steady increase in the number of species not taken by the 1971 sampling from deep water to shallow subtidal depths. The inference from these data is that oil may accumulate subtidally in shallower waters but not in the greater depths. Oil in the shallower waters would then tend to eliminate formerly abundant shallow-water species.
- (2) A number of common intertidal invertebrates and one fish (the common stickleback) were completely absent from the high-impact areas, although often collected or observed in 1958 and 1966 in the same region. These same species were reported by local scientists as common before the spill. Those forms most conspicuous by their absence were chitons, large limpets, large and small pelecypods and large gastropods. Apparently, the molluscan fauna is the most susceptible to the toxic effects of diesel fuel. This was also noted by Sanders and Blumer (personal communication).



- (3) Although there was little difference between numbers of megafauna from region to region, the control area on Orcas Island was the richest of all regions sampled. Lummi Island had the lowest standing crop, a phenomenon common to this island, as reported by local scientists.
- (4) Diversity indices calculated for $1/2\text{-m}^2$ megafaunal samples indicate that low diversity occurs in naturally stressed areas such as the upper intertidal zone with its poor water retention and often high ground- or fresh-water influx. Highest diversity indices for the megafauna were calculated from data taken in the lower intertidal zone, the habitat with the greatest stability and predictability of environmental factors.
- (5) Lowest megafaunal diversity figures were obtained from the lower and middle intertidal zones at traverse III on Guemes Island and Saddlebag Island, both areas of high spill impact and thus under unnatural stress conditions.
- (6) Lowest counts of meiofauna (200- to 750- μ) were made on samples taken at Guemes traverses III and V — somewhat naturally stressed by low salinity groundwater and unnaturally stressed by oil accumulations. Low counts were also found throughout most of the portions of the Lummi Island traverses, an apparently naturally stressed region.
- (7) Average populations of meiofauna were plotted as numbers/ m^2 . These figures reveal that the largest standing crops were found in the control area on Orcas Island. The Guemes impact area had half the numbers/ m^2 found on Hat Island (presumed to be unaffected by the spill) and one third the number found in the Orcas Island traverses.
- (8) The low Guemes counts were at the lower intertidal zone, where it was already established that environmental conditions are the most stable and predictable of the intertidal zones. One must then conclude that the lower intertidal zone of Guemes Island is now unnaturally stressed.



- (9) Graphs of meiofaunal diversity indices illustrate that the lowest diversities were obtained from the areas of largest visible amounts of oil, suggesting unnatural stress conditions. Highest indices were calculated from samples taken in the upper intertidal in all regions; lowest, in the lower intertidal. These figures are a result of numerical artifacts inherent in calculating ratios from areas where small numbers of species are represented by small numbers of individuals. (A 2:2 ratio yields 1.00.)
- (10) There is some evidence that diesel fuel may be toxic to endemic microflora of sediments and that the apparently low metabolic rates of marine bacteria in the Puget Sound region preclude their consumption of large quantities of oil.
- (11) Data indicate that groundwater seepage during low tides may markedly reduce cell counts of marine bacteria in marine sediments.
- (12) The wide dissemination of oil within the sediments of the high spill impact areas indicates that the tides play a major role in the deposition of oil vertically along a high-relief shoreline. In the case of the Anacortes spill, the oil moved to the southern shore of Guemes Island; as the tide receded, the thin diesel oil appears to have penetrated the entire surface of the intertidal zone.
- (13) Visual evidence during the period of lowest tides reveals that a great deal of oil was still trapped subtidally to depths of at least 3 m. Large globules arose from the sediment surface when disturbed by an oar and were also observed to be rising from the mud without provocation. The thin diesel oil must be easily adsorbed onto sediment or plankton particles and thus carried to the subtidal bottom, where it becomes trapped for an indefinite period.
- (14) The revised procedure for hydrocarbon analysis of water showed diesel-oil fingerprints for samples taken from the intertidal regions of Guemes Island and the shallow subtidal area off the east side of Lummi Island. This would indicate that oil was still present in the water during the sampling period.



- (15) The gas chromatograph of one water sample shows some evidence that Cuernes Island might have been exposed to other spills of heavier oils than No. 2 diesel, so the south end of Cuernes should be examined more thoroughly for the possibility of other oil contents.



BIOLOGICAL TABLES
II-4 THROUGH II-16



Table II-4
SUFTIDAL MEGAFUNA OFF GUEMES ISLAND**

Depth (ft)	Taxa	Depth (ft)	Taxa	Depth (ft)	Taxa
90	<u>Abietinaria variabilis</u> * <u>Stichopus californiensis</u> <u>Luidia foliolata</u> * <u>Henricia leviuscula</u> <u>Mopalia</u> sp. <u>Ischnochiton mertensi</u> * <u>Calliostoma costatum</u> <u>Crepidula nummaria</u> <u>Calyptraea fastigata</u> <u>Oregonia gracilis</u> <u>Pugettia gracilis</u> <u>Pagurus tenuimanus</u> * <u>Pagurus splendescens</u> <u>Spirontocaris</u> sp.	36-45	<u>Laminaria</u> sp. Yellow sponge <u>Abietinaria variabilis</u> * <u>Abietinaria</u> sp. <u>Thiaria argentea</u> * <u>Halecium</u> sp.* <u>Clytia</u> sp.* <u>Terebratalia transversa</u> * <u>Pteraster</u> sp.* <u>Luidia foliolata</u> * <u>Henricia leviuscula</u> * <u>Crucigera zygophora</u> * <u>Mopalia</u> sp. <u>Balanus nubilis</u> * <u>Balanus rostratus</u> * <u>Scyra acutifrons</u> <u>Oregonia gracilis</u> * <u>Petrolisthes eriomereus</u> <u>Pagurus</u> <u>Cancer oregonensis</u>	30	<u>Sternopsis fessor</u> * <u>Lumbrineris latreilli</u> * <u>Nephtys ciliata</u> * <u>Armandia brevis</u> * <u>Amphiodia urtica</u> * <u>Yoldia</u> sp.* <u>Nucula</u> sp.* <u>Macoma nasuta</u> <u>Protothaca staminea</u> <u>Gammaridea</u> <u>Pinnixa schmitti</u> <u>Amphiodia urtica</u> * <u>Leptasterias hexactis</u> <u>Crago</u> sp. <u>Grammaridea</u>
				13	

* Not taken in 1971 subtidal survey.

** Sylvester, R.O., and F.L. Clogston, 1958.



Table II-5
DIVERSITY AND ABUNDANCE OF MEGAFUNA FROM
SAN JUAN ISLANDS TRAVERSES

Traverse	Location	Zone	Bottles	Taxa	No.	Diversity*
I	Guemes, West end	UIT	1, 2	<u>Acarida</u>	1	10/43
				<u>Acmaea digitalis</u>	1	
				<u>Balanus glandula</u>	22	
				<u>Cirripedia larva</u>	1	
				<u>Hemigrapsus nudus</u>	14	
				<u>Littorina scutulata</u>	2	
				<u>Littorina sitkana</u>	2	
				<u>Mytilus edulis</u>	5	
				<u>Nematoda</u>	4	
				<u>Nereis sp.</u>	1	
				<u>Acmaea pelta</u>	1	
				<u>Acmaea scutum</u>	1+	
				<u>Polyplacophora</u>	1	
				<u>Balanus glandula</u>	2	
	MIT		6, 7	<u>Clinocardium nuttalli</u>	1	13/64
				<u>Copepoda</u>	35	
				<u>Hemigrapsus nudus</u>	1	
				<u>Littorina scutulata</u>	5	
				<u>Mytilus edulis</u>	6+	
				<u>(Polychaeta)**</u>	(1+)	
				<u>Nematoda</u>	8	
				<u>Thais emarginata</u>	1	
				<u>Thais lamellosa</u>	1	
				<u>Panopea generosa</u> (seen, not collected)		1/1
	LIT		11, (14 lost)	<u>Pagurus sp.</u>	1	2/2
	Subtidal	15		<u>Strongylocentrotus</u>	1	
				<u>drobachiensis</u>	1	



Table II-5 (Contd)

Traverse	Location	Zone	Bottles	Taxa	No.	Diversity [*]
II	Guemes, East end	UIT	17A	(Acmaea digitalis) No random or epifauna sample taken <u>Balanus glandula</u> <u>Balanus cariosus</u> Above listed from 1958 study but not found in 1971	(5)	1/5
		MIT	19, 20	Gammarid amphipoda <u>Acmaea scutum</u> <u>Amphitrite</u> <u>Cucumaria</u> <u>Caprella</u> <u>Hemigrapsus nudus</u> <u>Idothea</u> <u>Lucina</u> <u>Nereis</u> sp. <u>Pagurus</u> <u>Paphia</u> <u>Pugettia</u> <u>Saxidomus</u> <u>Thais lamellosa</u> Above found in 1958 but not found in 1971	3	1/3
		LIT	22, 26	<u>Acmaea digitalis</u> <u>Balanus glandula</u> Copepoda <u>Mytilus edulis</u> (<u>Pisaster ochraceus</u>) <u>Pelecypoda</u> <u>Thais emarginata</u>	4 18 28 1 (1) 9 2	7/33

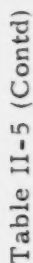
**services group**



Table II-5 (Contd)



Table II-5 (Contd)

Traverse	Location	Zone	Bottles	Taxa	No.	Diversity*
IV	Guemes, East end	LIT	116	(<u>Pisaster ochraceous</u>)	(1)	10/28
				(<u>Polychaeta</u>)	(3)	
		Subtidal	56, 57, 58	<u>Thais lamellosa</u>	1	6/17
				<u>Acmaea</u> sp.	2	
				<u>Calyptrea fastigata</u>	6	
				<u>Crepidula</u> sp.	1	
				<u>Pododesmus macrochisma</u>	6	
				<u>Pugettia gracilis</u>	1	
				<u>Pagurus</u> sp.	1	
V	Guemes, West end	UIT	61, 62, 66	<u>Acmaea personata</u>	5	7/44
				<u>Balanus cariosus</u>	2	
				<u>Balanus glandula</u>	2	
				<u>Hemigrapsus nudus</u>	5	
				<u>Littorina scutulata</u>	4	
				<u>Littorina sitkana</u>	25	
				<u>Mytilus edulis</u>	1	
				<u>Acmaea</u> sp.	1	
				<u>Balanus cariosus</u>	2	
				<u>Cancer antenarius</u>	1	
		MIT	116A, 117, 121	<u>Amphitrite</u> sp.	(7)	8/17
				<u>Hemigrapsus nudus</u>	1	
				<u>Ophiuroidea</u>	1	
				<u>Pagurus</u> sp.	1	
				<u>Thais lamellosa</u>	3	
				<u>Cancer productus</u>	2	
				<u>Cryptochiton stelleri</u>	1	
				<u>Hemigrapsus nudus</u>	29	
				<u>Gastropoda</u>	6	
				<u>Leptasterias hexactis</u>	3	
		LIT	110, 111, 115	<u>Mopalia hindsii</u>	1	10/47
				<u>Pagurus</u> sp.	2	
				<u>Pelecypoda</u>	2	
				<u>Cyanoplox dentiens</u>	1	



Table II-5 (Contd)

Traverse	Location	Zone	Bottles	Taxa	No.	Diversity**
V	Guemes, West end	Subtidal	59, 68, 122	<u>Clinocardium nuttalli</u> <u>Pagurus sp.</u> <u>Thais lamellosa</u>	4 1 1	3/6
VI	Guemes, East end	UIT	73	<u>Acmaea persona</u> <u>Acmaea scutum</u> <u>Hemigrapsus nudus</u> <u>Littorina scutulata</u> <u>Littorina sitkana</u> <u>Mytilus edulis</u> (<u>Acmaea scutum</u> - few) (<u>Amphitrite sp.</u>) <u>Cirratulidae</u> <u>Hemigrapsus nudus</u> <u>Macoma nasuta</u> (<u>Polychaeta</u> - few) <u>Acmaea persona</u> <u>Acmaea sp.</u> <u>Balanus glandula</u> <u>Glycera sp.</u> <u>Hemigrapsus nudus</u> <u>Leptasterias hexactis</u> (<u>Nereis sp.</u> - few) <u>Pinnixa sp.</u> (<u>Pisaster ochraceus</u>) (<u>Stichopus californiensis</u>) <u>Thais lamellosa</u> None (megafauna)	5 6 7 2 1 2 (5+) (3) 1 30 1 (5+) 1 1 3 1 3 10 (5+) 1 (1) (2) 1	6/23
		MIT	105, 106, 109			6/46
		LIT	101, 102			11/29
		Subtidal	69, 75			



Table II-5 (Contd)

Traverse	Location	Zone	Bottles	Taxa	No.	Diversity*
VII	Huckleberry Island	UIT	78, 79, 81A	<u>Balanus glandula</u>	12	6/21
				<u>Hemigrapsus nudus</u>	1	
				<u>Littorina scutulata</u>	2	
				<u>Littorina sitkana</u>	4	
				<u>Protothaca staminea</u>	1	
		MIT	82, 83, 84	<u>Tapes semidecussata</u>	1	8/58
				<u>Acmaea persona</u>	1	
				<u>Balanus cariosus</u>	1	
				<u>Balanus glandula</u>	10	
				<u>Cucumaria</u> sp.	1	
		LIT	87, 88, 89	<u>Hemigrapsus nudus</u>	7	6/19
				<u>Littorina scutulata</u>	19	
				<u>Littorina sitkana</u>	15	
				<u>Thais lamellosa</u>	4	
				<u>Hemigrapsus nudus</u>	9	
VIII	Saddlebag Island	Subtidal	76	(<u>Ophiuroidea</u>)	(1)	10/47
				<u>Pagurus</u> sp.	2	
				(<u>Polychaeta</u>)	(1)	
				<u>Stichopus californiensis</u>	1	
				<u>Thais lamellosa</u>	5	
		UIT	133 (lost), 134 127, 128, 129	No megafauna		
				Nothing observed		
				<u>Balanus glandula</u>	2	
				<u>Anthopleura</u> sp.	1	
				<u>Calliostoma ligatum</u>	1	
		MIT		<u>Hemigrapsus nudus</u>	15	
				<u>Macoma nasuta</u>	1	
				<u>Mytilus edulis</u>	2	
				<u>Pinnixa</u> sp.	1	



Table II-5 (Contd)

Traverse	Location	Zone	Bottles	Taxa	No.	Diversity*
VIII	Saddlebag Island	MIT	127, 128, 129	<u>Protothaca staminea</u>	1	10/47
				<u>Thais lamellosa</u> (narcotized) (Tunicates - several)	12 (10+)	
		LIT	90, 91, 93, 96	<u>Clinocardium nuttalli</u>	1	5/68
				<u>Hemigrapsus nudus</u>	3	
				<u>Leptasterias hexactis</u>	1	
				<u>Nephtys</u> sp.	6	
		Subtidal	126, 151	<u>Thais lamellosa</u> (narcotized)	57	5/12
				<u>Cancer magister</u>	1	
				<u>Crago</u> sp.	7	
				<u>Leptasterias hexactis</u>	1	
				<u>Spirogonocaris</u> sp.	2	
IX	Hat Island	UIT	144, 145, 149	<u>Macoma nasuta</u>	1	6/33
				<u>Acmaea scutum</u>	1	
				<u>Acmaea persona</u>	4	
				<u>Hemigrapsus nudus</u>	18	
				<u>Littorina scutulata</u>	20	
				<u>Littorina sitkana</u>	3	
				(<u>Mytilus edulis</u> - few)	(5)	
				<u>Balanus glandula</u>		
				Above listed in 1958 but not found in 1971		
				(<u>Acmaea</u> sp.)	(9)	
		MIT	139 (lost), 139A, 140	<u>Balanus glandula</u>	81	8/123
				<u>Cryptocanthodes</u> sp.	2	
				Gammaeidae	1	
				<u>Hemigrapsus nudus</u>	18	
				<u>Littorina scutulata</u>	2	
				<u>Mytilus edulis</u>	9	
				(<u>Idothea</u> sp.)	(1)	



Table II-5 (Contd)

Traverse	Location	Zone	Bottles	Taxa	No.	Diversity*
IX	Hat Island	MIT	139(lost), 139A, 140	<u>Pugettia producta</u> Above listed in 1958 but not found in 1971		8/123
		LIT	97, 98	<u>Acmaea scutum</u> (<u>Amphipoda</u> - few) (<u>Amphitrite</u> sp.) <u>Cancer antenarius</u> <u>Hemigrapsus nudus</u> (<u>Isopoda</u> - few) <u>Leptasterias hexactis</u> <u>Petrolisthes eriomerus</u> <u>Pugettia producta</u> <u>Diodora aspera</u> <u>Pododesmus</u> sp. <u>Pyura</u> sp. <u>Mopalia</u> sp. Above listed in 1958 but not found in 1971	12 (5+) (2) 1 5 (5+) 7 1 4	9/42
X	Orcas Island, Deer Point Control	Subtidal	138	<u>Maldanidae</u> <u>Nereis</u> sp.	37 1	2/38
		UIT	153, 154, 155, 159	<u>Acmaea persona</u> (<u>Amphipoda</u> - many) <u>Balanus glandula</u> (<u>Cancer</u> sp.) <u>Hemigrapsus nudus</u> <u>Littorina scutulata</u> <u>Mytilus edulis</u> <u>Acmaea digitalis</u> <u>Acmaea scutum</u> <u>Balanus cariosus</u>	8 (50+) 1 (1) 10 10 6 5 4 11+	7/95
		MIT	160, 161, 165			8/72



Table II-5 (Contd)



Table II-5 (Contd)

Traverse	Location	Zone	Bottles	Taxa	No.	Diversity*
XI	Orcas Island, Deer Point Control	LIT	184, 185, 188	<u>Acmaea</u> <u>scutum</u>	6	14/85
				(Amphipoda — many)	(50+)	
				<u>Amphitrite</u> sp.	5	
				<u>Balanus</u> <u>cariosus</u>	3	
				<u>Cancer</u> <u>productus</u>	4	
				<u>Hemigrapsus</u> <u>nudus</u>	4	
				<u>Katherina</u> <u>tunicata</u>	3	
				<u>Littorina</u> <u>sitkana</u>	1	
				<u>Leptasterias</u> <u>hexactis</u>	2	
				<u>Pagurus</u> sp.	1	
				<u>Petrolisthes</u> <u>eriomerus</u>	2	
				<u>Pugettia</u> <u>gracilis</u>	1	
				<u>Saxidomus</u> <u>giganteus</u>	1	
				<u>Thais</u> <u>lamellosa</u>	2	
				No megafauna in samples		
XII	Orcas Island, Deer Point Control	UIT	202, 203, 204	<u>Acmaea</u> <u>digitalis</u>	5	6/11
				<u>Acmaea</u> <u>persona</u>	2	
				<u>Acmaea</u> <u>scutum</u>	1	
				<u>Acmaea</u> sp.	1	
				<u>Hemigrapsus</u> <u>nudus</u>	1	
	MIT	198, 199, 201		<u>Mytilus</u> <u>edulis</u>	1	4/5
				<u>Acmaea</u> <u>digitalis</u>	1	
				<u>Acmaea</u> <u>scutum</u>	2	
				<u>Glycera</u> sp.	1	
				<u>Littorina</u> <u>scutulata</u>	1	
	LIT	192, 193, 196		<u>Acmaea</u> <u>scutum</u>	10	5/18
				(<u>Balanus</u> sp. — few)	(5+)	
				<u>Glycera</u> sp.	1	
				<u>Nereis</u> sp.	1	
				<u>Polydontidae</u>	1	
	Subtidal	208, 210		No megafauna in samples		



Table II-5 (Contd)

Traverse	Location	Zone	Bottles	Taxa	No.	Diversity*
XIII	Padilla Bay	UIT	213A, 216	<u>Acmaea persona</u>	1	5/18
				<u>Littorina scutulata</u>	2	
				<u>Littorina sitkana</u>	5	
				(Amphipoda — few)	(5+)	
XIV, XV		MIT		(Balanus sp. — few)	(5+)	
				Not sampled		
				Not sampled		
				Not sampled		
XVI		Subtidal		Trawls and grabs in bay center		
XVII	Lummi Island	UIT	279, 281 283, 285, 288	(Isopoda and Amphipoda only)		2/50 9/30
				<u>Acmaea digitalis</u>	5	
				<u>Acmaea persona</u>	1	
				(Balanus, just settled)	(10+)	
				<u>Cancer productus</u>	1	
				<u>Cryptocanthodes</u> sp.	2	
				<u>Hemigrapsus nudus</u>	2	
				<u>Littorina scutulata</u>	1	
				<u>Mytilus edulis</u>	7	
				<u>Pagurus</u> sp.	1	
				<u>Cancer productus</u>	1	
				<u>Cryptocanthodes</u> sp.	2	
				<u>Sicyogaster maeandricus</u> (clingfish)	1	
				<u>Hemigrapsus nudus</u>	1	
XVIII	Lummi Island	Subtidal	275, 277	<u>Pagurus</u> sp.	1	5/6
				No megafauna in samples		
				Dead Cancer productus only		
XVIII	Lummi Island	UIT	308, 309, 310			0/0



Table II-5 (Contd)

Traverse	Location	Zone	Bottles	Taxa	No.	Diversity*
XVIII	Lummi Island	MIT	302, 306, 307	(Polychaetes - many)		1 / 50+
		LIT	297, 298A, 301	(Amphipoda) Pelecypoda Polychaeta Fish	(11) 2 4 1	4 / 18
		Subtidal	294, 296	No megafauna in samples		

*

Simple diversity = $\frac{\text{number of taxa}}{\text{number of individuals}}$

**

Parentheses denotes from field notes.



Table II-6

COMPARISON BETWEEN INTERTIDAL MEGAFAUNA,
GUEMES ISLAND, MAY 1971 AND SUMMER 1958

	1971	1958**
UIT	<i>Acmaea digitalis</i> <i>Acmaea persona</i> <i>Acmaea scutum</i> <i>Balanus cariosus</i> <i>Balanus glandula</i> <i>Cirripedia larvae</i> <i>Hemigrapsus nudus</i> <i>Littorina scutulata</i> <i>Littorina sitkana</i> <i>Mytilus edulis</i> <i>Thais emarginata</i> <i>Thais lamellosa</i>	<i>Acmaea digitalis</i> <i>Acmaea sp.</i> * <i>Bankia setacea</i> <i>Balanus cariosus</i> <i>Balanus glandula</i> <i>Limnoria lignorum</i> * <i>Mytilus edulis</i>
MIT	<i>Acmaea digitalis</i> <i>Acmaea pelta</i> <i>Acmaea scutum</i> <i>Amphitrite cf. cirrata</i> <i>Anemones</i> <i>Anthopleura sp.</i> <i>Balanus cariosus</i> <i>Balanus glandula</i> <i>Balanus speciosus</i> <i>Cancer antenarius</i> <i>Clinocardium nuttalli</i> <i>Hemigrapsus nudus</i> <i>Idothea sp. cf. wosnesenski</i> <i>Littorina scutulata</i> <i>Macoma nasuta</i> <i>Mytilus edulis</i> <i>Ophiuroidea</i> <i>Pagurus sp. cf. granosissimus</i> <i>Polychaeta</i> <i>Protothaca staminea</i> <i>Thais emarginata</i> <i>Thais lamellosa</i>	<i>Acmaea digitalis</i> <i>Acmaea scutum</i> <i>Amphitrite cirrata</i> <i>Callianassa californiensis</i> * <i>Cancer gracilis</i> * <i>Cucumaria miniata</i> * <i>Hemigrapsus nudus</i> <i>Littorina sitkana</i> <i>Nereis sp.</i> <i>Pagurus granosissimus</i> <i>Protothaca staminea</i> <i>Saxidomus nutalli</i> *

** Sylvester, R.O. and F.L. Clogston, 1958

* Taxa not collected in 1971



Table II-6 (Contd)

	1971	1958
LIT	<i>Acmaea digitalis</i> <i>Acmaea persona</i> <i>Acmaea</i> sp. <i>Amphitrite</i> cf. <i>cirrata</i> <i>Anthopleura</i> sp. <i>Balanus glandula</i> Blenny <i>Cancer antenarius</i> <i>Cancer productus</i> <i>Cryptochiton stelleri</i> <i>Cyanoplax dentiens</i> Gastropoda <i>Glycera</i> sp. <i>Hemigrapsus nudus</i> <i>Leptasterias hexactis</i> <i>Mopalia hindsi</i> <i>Mytilus edulis</i> <i>Nereis</i> sp. <i>Pagurus</i> sp. <i>Panope generosa</i> Pelecypoda <i>Pinnixa</i> sp. <i>Pisaster ochraceous</i> Polychaeta <i>Stichopus californiensis</i> <i>Thais emarginata</i> <i>Thais lamellosa</i>	<i>Caprella</i> sp.* <i>Glycera</i> sp. <i>Idothea wosnesenskii</i> <i>Lacuna</i> sp.* <i>Macoma nasuta</i> <i>Pagurus</i> sp. <i>Pugettia producta</i>* <i>Thais emarginata</i>

*Taxa not collected in 1971



Table II-7

SPECIES FOUND IN INTERTIDAL AREAS ON MAINLAND
BETWEEN FERNDALE AND PADILLA BAY *
(not taken in 1971 study)

Species	Year Taken	Species	Year Taken
<i>Arenicola pusilla</i>	1958	<i>Mya arenaria</i>	1958
<i>Aemaea cassis</i>	1966	<i>Paphia staminea</i>	1958
<i>Batillaria zonalis</i>	1958	<i>Podocemus macrochesma</i>	1958
<i>Boltenia villosa</i>	1958	<i>Petrolisthes princeps</i>	1966
<i>Callinassa californiensis</i>	1966	<i>Polinices</i> sp.	1966
<i>Caprella</i> sp.	1958	<i>Pyura aspersa</i>	1958
<i>Cnemidocarpa firmarkeinsis</i>	1958	Sabellid worms	1958
<i>Diodora aspersa</i>	1958	<i>Tealia crassicornis</i>	1958, 1966
<i>Evasterias troscheli</i>	1966	<i>Telmessus cheiragonus</i>	1958
<i>Gasterosteus aculeatus</i>	1958	<i>Terebratula transversa</i>	1958
<i>Glycera</i> sp.	1958	<i>Tonicella lineata</i>	1966
<i>Halocystis</i> sp.	1958	<i>Tritonalia japonica</i>	1958
<i>Henricia leriusecula</i>	1958	<i>Upogebia pugettensis</i>	1958
<i>Lacuna</i> sp.	1958		

* Sylvester, R. O., and F. L. Clogston, 1958.

Sylvester, R. O., D. A. Carlson, R. F. Christman, and R. T. Oglesby, 1966.



Table II-8
SIMPLE DIVERSITY* — MEGAFUNA

	Tide Level	Traverses					
		I		II		III	
Guemes	UIT	10/43	0.23	1/5	0.20	8/50	0.16
	MIT	13/64	0.20	1/3	0.33	10/76	0.13
	LIT	1/1	1.00	7/33	0.21	None	0.00
	SST } DST }	2/2	1.00	6/23	0.26	14/38	0.37
		IV		V		VI	
	UIT	5/28	0.18	7/44	0.16	6/23	0.26
	MIT	8/21	0.38	8/17	0.48	6/46	0.13
	LIT	10/28	0.36	10/47	0.21	11/29	0.38
	SST } DST }	6/17	0.35	3/6	0.50	None	0.00
		VII (Huckleberry)		VIII (Saddlebag)		IX (Hat)	
Small Islands	UIT	6/21	0.29	None	0.00	6/33	0.18
	MIT	8/58	0.14	10/47	0.21	8/123	0.07
	LIT	6/19	0.32	5/68	0.07	9/42	0.21
	SST } DST }	None	0.00	5/12	0.42	2/38	0.05
		X		XI		XII	
Orcas (Control)	UIT	7/95	0.07	6/41	0.15	6/11	0.55
	MIT	8/72	0.11	11/88	0.13	4/5	0.80
	LIT	8/73	0.11	14/85	0.17	5/18	0.28
	SST } DST }	None	0.00	None	0.00	None	0.00
		XVII		XVIII			
Lummi	UIT	2/50	0.04	None	0.00		
	MIT	9/30	0.30	1/50	0.02		
	LIT	5/6	0.83	4/18	0.22		
	SST } DST }	None	0.00	None	0.00		
		XIII					
Padilla	UIT	5/18	0.28				
	MIT	Not sampled					
	LIT	Not sampled					
	SST	Not sampled					
	DST	Not sampled					

*
$$\frac{\text{Number of taxa}}{\text{Number of individuals}} / 1/2 \text{ m}^2$$



Table II-9
SALINITIES OF WATER SAMPLES
(determined by AgNO_3 titration*)

Traverse	Sample No.	Tide Level	Salinity (ppt)	Traverse	Sample No.	Tide Level	Salinity (ppt)
Guemes Is.				Orcas Is.			
I	3	UIT	25.64	X	152	SST	29.03
	8	MIT	26.98		156	UIT	4.42
	13	LIT	22.77		162	MIT	12.09
	16	SST	25.24		171	LIT	30.24
II	25	LIT	8.86		172	DST	28.64
	28	SST	27.33	XI	189	DST	31.33
III	37	MIT	15.37		190	SST	30.40
	40	LIT	25.59	XII	207	SST	31.18
	42	SST	25.09	Padilla Bay			
	213	DST	28.73	XIII	217	UIT	27.61
IV	49	MIT	27.16	XV	223	SST	24.94
	54	UIT	23.76	Lummi Is.			
	55	SST	27.42	XVII	276	SST	28.69
V	60	DST	27.85		278	DST	29.57
	64	UIT	28.15		291	LIT	28.95
	67	SST	19.93	XVIII	293	SST	29.52
	114	LIT	20.58		295	DST	26.67
VI	70	DST	26.17		298	LIT	25.98
	74	SST	22.86		303	MIT	21.92
Small Islands							
VII	77	DST	25.98				
	117A	SST	29.91				
VIII	94	LIT	32.07				
	124	DST	31.28				
	125	SST	27.64				
	130	MIT	27.46				
IX	137	DST	28.59				
	146	UIT	00.50				
	150	SST	28.74				

* Harvey, 1963, page 127.



Table II-10

QUANTITATIVE TOTAL ANIMAL COUNTS AND DIVERSITY
OF QUADRAT (1/2-M²) AND VAN VEEN (1/25-M²) GRAB SAMPLES
AT ALL SAMPLING LEVELS

Traverse	Tide Level	1/2-m ² Quadrat			1/25-m ² Van Veen (or equivalent)		
		Number of Taxa	Total Animals	Diversity Index	Number of Taxa	Total Animals	Diversity Index
		GUEMES ISLAND					
I	UIT	17	76	0.09	3	6	0.50
	MIT	10	114	0.09	3	73	0.04
	LIT	4	6	0.66	4	6	0.66
	SST	Not taken			15	482	0.03
	DST	Not taken			6	111	0.05
II	UIT	1	5	0.20	7	507	0.01
	MIT	4	8	0.50	11	1680	0.008
	LIT	4	78	0.05	9	80	0.11
	SST	Not taken			9	406	0.02
	DST	Not taken			13	432	0.03
III	UIT	5	29	0.17	11	188	0.06
	MIT	12	230	0.05	10	122	0.09
	LIT	Not taken			11	95	0.11
	SST	Not taken			9	69	0.13
	DST	Not taken			14	141	0.10
IV	UIT	4	13	0.30	13	2931	0.004
	MIT	7	44	0.16	15	1447	0.01
	LIT	6	22	0.17	Not taken		
	SST	Not taken			Not taken		
	DST	Not taken			19	1499	0.01
V	UIT	3	41	0.07	8	28	0.29
	MIT	8	143	0.06	16	23467	0.001
	LIT	11	124	0.09	16	2681	0.006
	SST	Not taken			4	507	0.008
	DST	Not taken			8	214	0.04
VI	UIT	4	23	0.17	10	89	0.11
	MIT	5	39	0.13	11	664	0.02
	LIT	11	80	0.14	Incomplete		
	SST	Not taken			6	2736	0.002
	DST	Not taken			Incomplete		



Table II-10 (Contd)

Traverse	Tide Level	1/2-m ² Quadrat			1/25 m ² -Van Veen (or equivalent)			
		Number of Taxa	Total Animals	Diversity Index	Number of Taxa	Total Animals	Diversity Index	
VII	SMALL ISLANDS	UIT	5	19	0.26	13	122	0.11
		MIT	3	31	0.10	10	291	0.03
		LIT	12	74	0.16	18	11544	0.002
		SST	Not taken		Not taken			
		DST	Not taken		Incomplete			
	VIII	UIT	Incomplete		0.09	10	523	0.02
		MIT	9	104	0.03	10	888	0.01
		LIT	5	193		10	4171	0.002
		SST	Not taken			10	1452	0.007
		DST	Not taken			5	12	0.42
IX	UIT	3	40	0.08	9	119	0.08	
	MIT	9	129	0.07	13	1486	0.009	
	LIT	13	512	0.03	7	28	0.25	
	SST	Not taken			Not taken			
	DST	Not taken			8	136	0.06	
X	ORCAS ISLAND	UIT	9	66	0.14	8	420	0.02
		MIT	10	65	0.15	11	479	0.02
		LIT	14	7687	0.002	14	545	0.03
		SST	Not taken			11	968	0.01
		DST	Not taken			Incomplete		
	XI	UIT	2	8	0.25	5	54	0.09
		MIT	7	46	0.15	9	1706	0.005
		LIT	8	42	0.19	8	3961	0.002
		SST	Not taken			Incomplete		
		DST	Not taken			12	390	0.03
	XII	UIT	3	11	0.27	3	52	0.06
		MIR	5	6	0.83	6	47	0.13
		LIT	6	46	0.13	Incomplete		
		SST	Not taken			8	342	0.02
		DST	Not taken			4	57	0.08



Table II-10 (Contd)

Traverse	Tide Level	1/2-m ² Quadrat			1/25 m ² -Van Veen (or equivalent)		
		Number of Taxa	Total Animals	Diversity Index	Number of Taxa	Total Animals	Diversity Index
PADILLA BAY							
XIII	UIT	8	47	0.17	10	187	0.05
		No Other Levels Sampled					
XIV	SST				11	4243	0.003
		No Other Levels Sampled					
XV	SST				14	4246	0.003
		No Other Levels Sampled					
XVI	SST				16	5189	0.003
		No Other Levels Sampled					
LUMMI ISLAND							
XVII	UIT	3	10	0.30	3	23	0.13
	MIT	5	5	1.00	6	78	0.08
	LIT	9	656	0.01		Not taken	
	SST		Not taken			Incomplete	
	DST		Not taken			Incomplete	
XVIII	UIT	2	7	0.29	5	124	0.04
	MIT	11	546	0.02	9	730	0.01
	LIT	13	6572	0.002	13	8945	0.001
	SST		Not taken			Incomplete	
	DST		Not taken		7	39821	0.0002



Table II-11

COMPOSITION OF NONQUANTITATIVE
PLANKTON SAMPLES FROM PADILLA BAY

<u>Zooplankton</u>			<u>Phytoplankton</u>	
ST-XIV 222	Hydrozoa	13	Coscinodiscus sp.	Most abundant
	Turbellaria*	1	Nitzschia sp.	Abundant
	Nematoda*	18	Gyrosigma sp.	Abundant
	Gastropoda*	10	Grammatophora sp.	Common
	Nudibranchia*	18	Meridion sp.	Common
	Polychaeta*	136	Synedra sp.	Common
	Copepoda	4,258		
	Amphipoda*	2		
	Cumacea*	2		
	Zoea	207		
	Nauplii	744		
	TOTAL	5,409		
ST-XV 227	Nematoda*	11	Coscinodiscus sp.	Abundant
	Gastropoda*	2	Nitzschia sp.	Abundant
	Polychaeta*	66	Gyrosigma sp.	Abundant
	Cladocera	98	Grammatophora sp.	Common
	Copepoda	1,000	Fragilaria sp.	Common
	Cirripedia larvae	46	Isthmia sp.	Common
	Amphipoda*	1	Ulothrix sp.	Common
	Caprellidae*	1	Navicula sp.	Common
	Cumacea*	1		
	Mysidacea	11		
	Tunicata larvae	7		
	Brachyura larvae	50		
	Nauplii larvae	40		
	Tanaidacea*	6		
	TOTAL	1,340		
ST-XVI 232	Hydrozoa	1	Coscinodiscus sp.	Abundant
	Nematoda*	8	Nitzschia sp.	Abundant
	Gastropoda*	3	Gyrosigma sp.	Abundant
	Polychaeta*	30	Isthmia sp.	Common
	Acarida*	1	Fragillaria sp.	Common
	Cladocera	15	Cocceneis sp.	Common
	Copepoda	703	Tricornutum sp.	Common
	Cirripedia larvae	88		
	Amphipoda*	2		
	Cumacea*	1		
	Mysidacea	48		
	Tunicata larvae	23		
	Brachyura larvae	33		
	Nauplii larvae	96		
	Tanaidacea*	3		
	TOTAL	1,053		

* Benthic taxa



Table II-12
AVERAGE MEIOFAUNA COUNTS/M² BY TIDE LEVELS AND AREAS

	UIT	MIT	LIT
Average of all areas	8,749	21,398	122,660
Difference from average			
Guemes Island	High +10,701	High +23,631	Very Low -115,079
Small Islands	Low -2,232	Low -7,773	High +23,227
Orcas Island	Low -4,099	Low -4,557	Very High +91,852
Padilla Bay	High +2,709	Low -9,942	Very Low -111,204
Lummi Island	Very Low -7,079	Low -11,298	Very Low Not Calculated
Lowest to Highest	Lummi Island Orcas Island Small Islands Padilla Bay Guemes Island	Lummi Island Padilla Bay Small Islands Orcas Island Guemes Island	Guemes Island Padilla Bay Lummi Island Small Islands Orcas Island



Table II-13

DIVERSITY INDEX FOR MEIOFAUNA IN 1/25-M² VAN VEEN GRABS*

	Traverse	Sample No.	Tide Level	No. of Taxa	Total Animals	Diversity Index	Tide-Level Average Diversity Index
Guemes	I	9	MIT	3	73	4.0	UIT 9.3 MIT 16.2 LIT 7.5
		11	LIT	4	6	67.0	
	II	17A	UIT	7	659	1.0	
		20	MIT	10	1680	1.0	
	III	23	LIT	9	80	11.0	
		33	UIT	10	188	5.0	
		38	MIT	10	122	8.0	
	IV	41	LIT	10	95	11.0	
		53	UIT	12	926	0.4	
		46	MIT	14	1468	1.0	
	V	66	UIT	8	28	29.0	
		115	LIT	13	1032	1.0	
	VI	121	MIT	11	6800	0.2	
		72	UIT	10	89	11.0	
		109	MIT	11	664	2.0	
Huckle-berry	VII	81A	UIT	12	116	10.0	
		83	MIT	10	291	3.0	
		88	LIT	11	7500	0.2	
Saddle-bag	VIII	90	LIT	10	4171	0.2	UIT 6.3 MIT 1.7 LIT 0.2
		128	MIT	11	888	1.0	
		134	UIT	10	522	2.0	
Hat	IX	139A	MIT	5	480	1.0	
		149	UIT	9	136	7.0	
Orcas (Control)	X	159	UIT	7	452	2.0	UIT 5.7 MIT 5.0 LIT 1.5
		165	MIT	9	735	1.0	
		169	LIT	11	13,200	0.1	
	XI	176	UIT	5	54	9.0	
		183	MIT	10	1809	1.0	
		188	LIT	9	3961	0.2	
	XII	201	MIT	6	47	13.0	
		204	UIT	3	52	6.0	

*
$$DI = \frac{\text{number of taxa}}{\text{number of individuals}} \times 100$$



Table II-13 (Contd)

Traverse		Sample No.	Tide Level	No. of Taxa	Total Animals	Diversity Index	Tide-Level Average Diversity Index
Padilla	XIII	216	UIT		287		
	XIV	221	UIT		687		
	XV	226	UIT		184		
	XVI	231	UIT		675		
Lummi	XVII	281	UIT	5	23	22.0	
		288	MIT	6	78	8.0	UIT 13.0
	XVIII	307	MIT	11	730	6.0	MIT 7.0
		310	UIT	5	134	4.0	LIT -



Table II-14
MICROBIOLOGICAL DATA FROM ANACORTES SPILL SURVEY

Station Designation	Station Location	Condition of Environment	Cell Count/cc Via		Diversity No. of Colony Types
			Direct Microscopic	Luminescence Biometer	
I, UIT	Guemes W end	Rainbow sheen in pool Oil seeping from mud Oil sheen and odor	4.0×10^8	4.39×10^7	7
I, MIT	Guemes W end		2.5×10^8	4.87×10^7	10
I, LIT	Guemes W end		1.2×10^9	1.99×10^7	6
II, UIT			4.8×10^8	5.55×10^7	11
II, MIT		Oil streaks on water Recent crab kill	1.7×10^9	6.79×10^6	10
II, LIT			1.3×10^9	4.15×10^7	12
III, UIT	E of ferry landing		5.0×10^7	1.52×10^7	11
III, MIT	E of ferry landing		4.0×10^8	2.49×10^7	9
IV, UIT		Sheen on water	1.0×10^8	3.54×10^6	6
IV, MIT			4.0×10^9	3.38×10^7	10
V, UIT	W side, populated cove		9.0×10^8	3.11×10^7	6
V, MIT	W side, populated cove		2.0×10^9	7.23×10^7	7
V, LIT	W side, populated cove	No evidence of oil	2.9×10^9	1.85×10^7	13
VI, UIT	W of SE tip of Guemes		7.2×10^9	5.39×10^7	10
VI, MIT	W of SE tip of Guemes		5.6×10^9	1.38×10^7	11



Table II-14 (Contd)

Station Designation	Station Location	Condition of Environment	Cell Count/cc Via		Diversity (No. of Colony Types)
			Direct Microscopic	Luminescence Biometer	
VI, LIT	W of SE tip of Guemes	Dead crabs; sheen under rocks	6.0×10^8	1.34×10^7	8
VII, UIT		Oil odor	2.3×10^8	5.50×10^7	9
VII, MIT		No oil odor	7.5×10^7	No detectable count	11
VII, LIT		Bad oil sheen and odor	2.5×10^8		18
VIII, UIT		Strong diesel odor	5.0×10^7	1.38×10^7	11
VIII, MIT		Sl. red sediments; oil conc. here	7.5×10^7	3.83×10^7	15
VIII, LIT		Oil sheen; dead grass	5.0×10^7	1.99×10^7	17
IX, UIT	Small cove, S side, Hat		5.0×10^7	2.48×10^6	10
IX, MIT		Rich fauna	2.0×10^8	3.02×10^7	13
IX, LIT		No evidence of oil	2.8×10^8	2.18×10^7	14
X, UIT	Small cove adj. to beach in front of settlement		1.0×10^8	8.84×10^6	19
X, MIT	Small cove adj. to beach in front of settlement		1.0×10^8	7.35×10^6	14
X, LIT	Small cove adj. to beach in front of settlement		1.0×10^8	No detectable count	11



Table II-14 (Contd)

Station Designation	Station Location	Condition of Environment	Cell Count/cc Via		Diversity (No. of Colony Types)
			Direct Microscopic	Luminescence Biometer	
XI, UIT	Small cove 200 yd W Deer Point		1.0×10^8	No detectable count	6
XI, MIT	Small cove 200 yd W Deer Point		1.2×10^8	3.02×10^6	11
XI, LIT	Small cove 200 yd W Deer Point		1.8×10^8	1.48×10^7	10
XII, UIT	Large cove NE Deer Point	Barren; drainage too good	7.5×10^7	1.82×10^7	3
XII, MIT	Large cove NE Deer Point	Naturally stressed, poor water retention	1.5×10^8	1.94×10^7	—
XII, LIT	Large cove NE Deer Point	Odor of decomposition	2.0×10^8	5.54×10^7	*
XIII, UIT	Padilla Bay	No sheen; cobble beach	1.6×10^8	2.89×10^7	7
XIV (Offshore)			1.2×10^9	2.38×10^7	6
XV (Offshore)			3.3×10^8	4.26×10^7	4
XVI (Offshore)			1.8×10^9	3.37×10^7	5
XVII, UIT	W side Lummi	Heavy euphaulid kill after spill	2.0×10^8	7.30×10^6	3
XVII, MIT		Coarse gravel, stressed beach	5.6×10^8	1.03×10^7	—
XVIII, UIT	E side Lummi	Possible crab kill	1.6×10^8	7.00×10^6	6
XVIII, MIT	E side Lummi		1.4×10^8	5.93×10^6	5
XVIII, LIT	E side Lummi	Sand flat w/tide pool	9.6×10^8	1.20×10^7	5



Table II-15
SEDIMENT ANALYSIS PERCENT FRACTION BY WEIGHT

Traverse and Sample No.	Size (mm)					
	> 4	4-2	2-1	1-0.50	0.50-0.25	<0.25
I-4 UIT	50.49	9.98	3.08	1.38	27.56	7.52
II-22 LIT	62.53	4.34	1.94	1.86	16.25	13.09
III-34 UIT	34.66	20.67	14.65	10.72	13.80	5.48
III-IV Trawl-DST	0.00	1.77	11.13	7.02	29.25	50.83
IV-52 UIT	32.30	8.07	6.60	26.57	20.32	6.14
IV-47 MIT	50.83	1.89	.90	6.67	31.49	8.23
IV-116 LIT	3.81	3.69	3.98	14.60	48.41	25.51
V-63 UIT	24.27	20.72	35.17	17.70	2.00	0.14
V-112 LIT	56.53	21.88	13.66	6.16	1.61	0.17
VI-103 LIT	27.33	33.70	21.40	10.82	5.95	0.81
VI-107 MIT	9.34	30.90	23.26	17.47	11.54	7.49
VII-81 UIT	28.64	25.26	23.12	18.69	3.82	0.48
VII-86 MIT	13.38	8.96	8.96	14.63	37.99	16.09
VIII-135 UIT	38.62	16.89	12.60	16.13	15.27	0.50
VIII-132 MIT	6.14	7.74	5.12	9.06	58.57	13.37
VIII-92 LIT	0.00	0.35	0.00	0.98	53.42	45.26
IX-147 UIT	54.45	29.81	11.97	2.95	0.72	0.10
IX-143 MIT	47.57	22.91	12.84	8.39	3.95	4.34
IX-99 LIT	52.88	17.25	9.99	6.18	3.09	10.62
X-158 UIT	39.84	10.83	5.97	10.08	20.56	12.71
X-164 MIT	18.33	21.36	9.19	10.75	33.49	6.89
X-168 LIT	1.99	0.92	0.43	0.19	7.00	89.48
XI-178 UIT	30.95	31.00	27.34	8.72	1.92	0.08
XI-182 MIT	35.01	23.11	19.26	9.56	8.34	4.72
XII-206 UIT	15.19	12.13	10.35	26.66	33.38	2.29
XII-200 MIT	27.86	21.08	20.27	15.45	10.88	4.47
XII-197 LIT	55.24	25.25	6.58	1.22	4.42	7.29
XIII-215 UIT	49.71	7.28	11.63	22.21	7.00	2.17
XVII-282 UIT	17.71	15.24	16.07	36.34	14.37	0.28
XVII-287 MIT	10.49	60.12	27.69	1.44	0.23	0.03
XVII-292 LIT	77.52	9.12	1.97	1.97	7.93	1.49
XVIII-312 UIT	47.07	7.46	2.95	14.51	25.62	2.40
XVIII-305 MIT	11.85	12.00	13.39	12.88	42.21	2.67
XVIII-300 LIT	9.69	10.40	7.51	16.98	32.90	9.69



Table II-16
SEDIMENT TYPES

Traverse and Sample No.		Sediment*	Traverse and Sample No.		Sediment*
I-4	UIT	Sandy cobbles	IX-143	MIT	Gravelly cobbles
II-22	LIT	Sandy cobbles	IX-99	LIT	Gravelly cobbles
III-34	UIT	Cobble sand	X-158	UIT	Sandy cobbles
III-IV	Trawl	Sandy-silty-clay	X-164	MIT	Sandy gravel
IV-52	UIT	Cobbly fine sand	X-168	LIT	Silty clay
IV-47	MIT	Sandy cobbles	XI-178	UIT	Sandy gravel
IV-116	LIT	Silty fine sand or very fine sand	XI-182	MIT	Gravelly cobbles
V-63	UIT	Cobbles to very coarse sand	XII-206	UIT	Sand
V-112	LIT	Pebbly cobbles	XII-200	MIT	Cobbly sand
VI-103	LIT	Cobbly gravel	XII-197	LIT	Gravelly cobbles
VI-107	MIT	Sandy gravel	XIII-215	UIT	Sandy cobbles
VII-81	UIT	Sandy cobbles	XVII-282	UIT	Sandy gravel
VII-86	MIT	Sand	XVII-287	MIT	Pebbles
VIII-135	UIT	Sandy cobbles	XVII-292	LIT	Cobbles
VIII-132	MIT	Fine sand	XVIII-312	UIT	Sandy cobbles
VIII-92	LIT	Silty sand	XVIII-305	MIT	Medium sand
IX-147	UIT	Gravelly cobbles	XVIII-300	LIT	Medium sand

* Classification:

Cobbles	> 4 mm
Pebbles	2-4 mm
Very coarse sand	1-2 mm
Coarse sand	1-0.50 mm
Medium sand	0.50-0.25 mm
Fine to very fine sand	0.25-0.062 mm
Silt and clay	< 0.062 mm



SECTION III

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APPENDIX A
SURVEY OF MORTALITY AT TWO AREAS
OF SOUTH BEACH OF GUEMES ISLAND*
APRIL 28 TO MAY 15, 1971

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APPENDIX A
SURVEY OF MORTALITY AT TWO AREAS
OF SOUTH BEACH OF GUEMES ISLAND
APRIL 28 TO MAY 15, 1971

A. INTRODUCTION

This report summarizes the sampling activities of the students of Huxley 322 (Pollution and Marine Ecology) on the south beach of Guemes Island between April 28, 1971, and May 15, 1971. As a study of mortality in the area's marine environment during this time, there are a number of deficiencies which must be noted.

First, it was late in getting started; no samples were taken before April 28, 1971, so possible immediate mortality could not be evaluated.

Second, it is very restricted in the areas covered; nothing was determined of the immediate persistent effect on the plankton of the area (including larval and juvenile fish), and possible effects on subtidal habitats were not monitored. Sampling was restricted to the obvious intertidal animals that commonly occur above the 0.0-ft tide line. Only two areas on the south shore of Guemes Island were monitored; the total area of beach damage was not determined. The Zostera beds that occur below the 0.0-ft tide line were not observed.

Third, sampling techniques were crude. In general, only the large individuals of a given species were recorded. When examining substrate samples, 5-mm² screens were used; thus, many small or juvenile forms escaped detection. Sampling times during the study interval were erratic according to tides and free class time. Identification in most cases was only to genera, and, at times, to higher taxonomic categories.

Hopefully, these data will complement others from more extensive studies in providing a comprehensive evaluation of damage to the marine organisms in the area of the diesel oil spill that occurred on April 26, 1971.



B. SUMMARY

If any short statement summarizing the damage to the invertebrates on the south beach of Guemes Island can be made, it is that many animals died. Of the species examined, all appear to have exhibited some mortality, none exhibited complete mortality, and some suffered greater mortality than others. There was limited persistent mortality in some species up to at least May 15, 1971.

Sampling efforts were at two areas of the south beach of Guemes Island approximately 0.75 mi east of the ferry terminal. One area was a cobble beach that had a rocky point in the low-tide area. Sampling began on April 28, 1971, with a 1-m wide transect from high to low tide at each sample area. Observation revealed many dead invertebrates along the transect. The most extensive mortality appeared in the chitons, limpets, and cockles. Other organisms were not dead but showed curious behavior. A mud shrimp (Upogebia) was observed crawling out of its burrow. The snail Thais had fallen off of rocks and was lying with its foot extended apparently anaesthetized.

A similar survey 3 days later (May 1, 1971) showed things to be generally unchanged. It was difficult to determine if the numbers of dead animals indicated continuing mortality or individuals that had died some time earlier but had not yet washed away. Increases in mortality at this time were noted in the pink Tellinid clams and the acorn barnacle Balanus glandula.

Sampling efforts after May 1, 1971, focused on specific problems. Differential mortality in Hemigrapsus was indicated. Generally, in samples of dead crabs, there were more females than males. Surviving shore crabs were much smaller than those that died. Of the surviving animals, there were more males than females.

The fate of the hundreds of Thais snails that appeared anaesthetized is not clear. If the population recovered, its distribution on May 15, 1971, at least was lower in the tide zone than on April 28, 1971.



The initial survey showed extensive mortality of the clam *Prototheca* in area 1. Fairly dense populations of this clam were observed in sample area 2 on May 15, 1971, although continuing mortality was indicated by the recent death of approximately 10 percent of the clam population.

To determine the condition of benthos, a 1-m² station 20 cm deep in the midtide region of sample area 2 was sampled on May 15, 1971. The station yielded numerous species in apparently good condition — particularly polychaetes. Diesel fuel was still apparent in these sediments at that time.

Other observations on May 15, 1971, indicated continuing mortality. A number of *Cancer productus* and a sea star, *Pisaster*, were observed freshly dead.

C. RESULTS

1. Sampling Areas

Two sampling areas were used to collect the data reported here. Area 1 was a cobble beach in the mid- to high-tide area that gave way to sandy areas over a heavy clay base near the low tide line. Area 2 also was a cobble beach in the mid- to high-tide area, but the lower part consisted of large rocks over a gravel base. Sampling at these two layers went only to the 0.0-ft tide mark; consequently, *Zostera* beds were not sampled. At 0.0-ft tide, area 1 was 129 ft to the high tide mark, and area 2 was 212 ft.

2. Sampling, April 28, 1971

a. Area 1

A transect 1-m wide from high tide to the 0.0-ft mark was examined and the mortality estimated for organisms that were large and readily observed. Generally, the dead and living individuals of all species were collected. Some species (mussel, *Mytilus*, barnacles *Balanus glandula* and *cariosus*, and oysters, *Crassostrea*) were not removed. All these were closed tight, indicating little or no mortality at this time. In the cobble part of area 1, organisms were removed from the rocks or the substrate immediately under the rocks. In the sandy areas, the substrate (down to the clay base) was sifted through 5-mm screens.



Table A-1
SAMPLE AREA 1, APRIL 28, 1971

Species	No. Dead	No. Alive
Organisms Collected on Surface		
<u>Acmaea</u>	149	-
<u>Calliostoma</u>	16	-
<u>Clinocardium</u>	22	4
<u>Littorina</u>	44	-
<u>Hemigrapsus</u>	75	77
<u>Mopalia</u>	1	-
Nemertean worms	12	-
<u>Glycera</u>	4	1
<u>Prototheca</u>	19	-
<u>Thais</u>	11	-
Tellinid clams	69	95
<u>Upogebia</u>	5	-
Organisms Collected by Sifting Sand		
<u>Acmaea</u>	2	1
<u>Crassostrea</u>	-	1
<u>Clinocardium</u>	8	-
<u>Eudestyia</u>	1	-
<u>Glycera</u>	-	20
<u>Hemigrapsus</u>	6	2
<u>Macoma</u>	-	14
<u>Saxidomus</u>	-	2
Tellinid clams	-	29
Nemertean worms	1	-
<u>Nereis</u>	-	7
<u>Amphitrite</u>	25	-
Other polychaetes	8	-
<u>Thais</u>	2	-
<u>Prototheca</u>	-	2
<u>Upogebia</u>	-	1*

* Observed out of its burrow crawling across sand.



1) Surface Animals (Table A-1)

As mentioned, the sessile, attached invertebrates were not visibly affected but the shelled gastropods were. There was virtually complete mortality in the limpets (Acmaea) and top shells (Calliostoma). Also, many dead organisms had washed up from some other part of the beach. Dead cockles (Clinocardium) and little-neck clams (Prototheca) were observed as well as a mud shrimp (Upogebia) out of its burrow and crawling on the surface (not yet dead but moving very slowly).

2) Sifted Sand (Table A-1)

The occurrence of dead organisms from other parts of the beach was noted (Acmaea, Hemigrapsus, Thais). There was also marked mortality in the cockles that were still buried in the sand. Mortality in the polychaete worms appeared variable. The Glycera and Nereis showed little mortality, whereas Amphitrite showed extensive mortality.

b. Area 2 (Table A-2)

Extensive mortality in the genus Acmaea was noted, and almost all chitons observed (mostly Mopalia) were dead. The most striking observation, however, concerned the whelk, Thais; 654 individuals were picked up in the transect. They had fallen off of rocks and had their foot extended, but they were not dead. When stimulated, the foot would slowly retract. It appeared that the snail was anaesthetized.

3. Sampling, May 1, 1971

The sampling program carried out on April 28 was repeated on May 1, 1971. Results are presented in Tables A-3 and A-4. Conditions at this time were substantially the same as on April 29.

There was a decrease in the total number of organisms observed—probably due to dispersal of those that had died. Dead animals were observed, but it was not possible in all cases to determine whether they had died since the



Table A-2
SAMPLE AREA 2, APRIL 28, 1971

Species	No. Dead	No. Alive
<u>Acmaea</u>	262	-
<u>Crassostrea</u>	-	2
<u>Clinocardium</u>	6	-
<u>Cancer productus</u>	1	-
<u>Isopod</u>	1	-
<u>Littorina</u>	- 20*	-
<u>Hemigrapsus</u>	21	(?)
<u>Evastarius</u>	5	1
<u>Mopalia</u>	17	-
<u>Thais</u>	- 654**	-
<u>Pagurus</u>	4	-
<u>Polychaetes</u>	5	-

* Fallen off of rocks and withdrawn into the shell.

** Fallen off of rocks; foot extended; apparently anaesthetized.

last sampling time or whether they had been previously dead and had not yet washed away. In a few cases, there were signs of continuing mortality. There were many more of the pink Tellinid clams on the surface, most of them dead. There were also signs of mortality in the barnacle, Balanus glandula. Study showed that 18 percent in the high-tide area, 14 percent in the midtide area, and 25 percent in the low-tide area were recently dead.

Behavioral abnormalities not observed previously were noted at this time. There were large numbers of sphaeromid isopods crawling around the substrate near the low-tide mark at area 2, and hermit crabs (Pagurus) were observed crawling under rocks without any shells.



Table A-3
SAMPLE AREA 1, MAY 1, 1971

Species	No. Dead	No. Alive
Organisms Collected on Surface		
<u>Acmaea</u>	189	29
<u>Clinocardium</u>	10	2
<u>Calliostoma</u>	9	-
<u>Cancer productus</u>	1	-
<u>Hemigrapsus</u>	11	144
<u>Macoma</u>	8	4
<u>Prototheca</u>	19	3
<u>Isopod</u>	1	-
<u>Littorina</u>	69	21
<u>Mopalia</u>	1	-
<u>Leptastarius</u>	1	-
<u>Pagurus</u>	1	1
<u>Polychaetes</u>	10	19
<u>Ophivroid</u>	1	-
<u>Tellinid clams</u>	103	37
<u>Upogebia</u>	1	-
Organisms Collected by Sifting Sand		
<u>Acmaea</u>	8	-
<u>Hemigrapsus</u>	-	3
<u>Mytilus</u>	-	1
<u>Thais</u>	3	-
<u>Littorina</u>	8	-
<u>Clinocardium</u>	-	1
<u>Prototheca</u>	4	1
<u>Tellinid clams</u>	-	31
<u>Glycera</u>	-	2
<u>Other polychaetes</u>	-	7



Table A-4
SAMPLE AREA 2, MAY 1, 1971

Species	No. Dead	No. Alive
<u>Acmaea</u>	279	34
<u>Mopalia</u>	15	5
<u>Evastarius</u>	2	6
<u>Clinocardium</u>	1	-
<u>Prototheca</u>	4	36
<u>Saxidomus</u>	-	1
<u>Macoma</u>	1	16
<u>Crassostrea</u>	-	1
<u>Calliostoma</u>	5	-
<u>Thais</u>	- 534 *	-
<u>Littorina</u>	2	5
<u>Pagurus</u>	2	3
<u>Cancer antenarius</u>	1	-
Isopods	1	3
Sipunculid worm	-	1
Polychaetes	21	19
Blennies	2	-

* Fallen off of rocks and withdrawn into shell.

4. Continuing Studies

a. The Shore Crab Hemigrapsus (Table A-5)

As already reported, Hemigrapsus suffered significant mortality during the week of April 28. Of a sample of dead animals collected, 36 were males (mean width, 1.07 cm) and 33 were females (mean width, 1.04 cm). A sample of living animals collected on April 28 showed 46 males (1.16-cm mean width) and 29 females (1.03-cm mean width). Later, on May 12 (Table A-6), large numbers of the crab were noticed on the beach, indicating continuing mortality. A sample of 44 of these dead crabs was collected and size and sex measurements taken. There was a preponderance of



Table A-5
HEMIGRAPSUS SIZE AND SEX DATA

	No.	Males Mean Width (cm)	No.	Females Mean Width (cm)
April 28, 1971				
Dead	36	1.07	38	1.04
Alive	46	1.16	29	1.03
May 12, 1971				
Dead	13	1.8	31*	1.8
May 15, 1971				
Alive**	142		118	

* 6 carrying eggs

** Mean size, 0.74 cm

Table A-6
MAY 12, 1971, 1-m² SAMPLE STATION

Species	No. Collected
<u>Acmaea</u>	14
<u>Littorina</u>	5
<u>Hemigrapsus</u>	41
<u>Thais</u>	23
<u>Pagurus</u>	46
<u>Prototheca</u>	15
<u>Macoma</u>	14
<u>Crassostrea</u>	1
<u>Leptastarius</u>	1
<u>Mytilus</u>	4
<u>Bittium</u>	33
<u>Amphitrite</u>	147
<u>Polychaetes</u> Sp A	1
B	5
C	10
D	4
E	21
F	34
<u>Balanus glandula</u>	present



females (70 percent) in the sample of dead crabs; of these females, 19 percent were carrying eggs. The mean size of the males was 18-mm carapace width; 18 mm for the females.

To determine the damage to the Hemigrapsus population, a series of stations were sampled on May 5, 1971. The size of the crabs in the samples was smaller than expected from previous sizes (station 1, 7 mm; station 2, 8 mm; station 3, 6 mm; station 4, 9 mm). In general, there was a greater percentage of males in the crabs collected. Of 270 individuals, 55 percent were males.

b. Transect

To determine what survived in the midtide region of sample area 2, a 1-m x 1-m transect was sifted through 0.5-mm screens to a depth of 20 cm on May 15, 1971. The sample station had a top layer of cobble-size rocks over a gravel base; with depth, the gravel contained more sediment material high in apparent organic matter and broken clam shells. The sediments contained obvious levels of persistent diesel fuel.

Although it is difficult to evaluate what organisms at what density should have been in the transect had there been no damage, the appearance was that organisms were plentiful and looked in relatively good condition. The polychaetes represented the most abundant group of organisms.

c. Thais population (Table A-7)

The fate of the Thais population that was apparently anaesthetized during the week of April 29 to May 7, 1971, was not clear. On May 12, 1971, a 0.5-m² area was sampled near the low tide line of sample area 2 and 43 Thais in apparently good condition were collected (which is about the population density encountered on April 28 and May 1, 1971). A second station at sample area 2 was established near the midtide area on May 12, 1971. This 0.5-m² plot yielded only two living Thais, a density that was much lower than



that encountered on April 28 and May 1, 1971. On May 15, 1971, however, a 1-m² plot in the midtide region of sample area 2 yielded 23 Thais.

The mean length of 40 Thais collected from sample area 2 on April 28, 1971, was 3.0 cm. On May 12, a sample of 43 Thais from area 2 had a mean shell length of 2.9 cm. The mean size of the Thais population from April 28 to May 15, then, apparently did not change. The data suggest that many of the Thais recovered from the anaesthetic condition noticed during the week of April 28.

Table A-7
THAIS SIZE DATA

	No.	Mean Length of Shell (cm)
Anaesthetized Animals Collected April 28, 1971	40	3.0
Collected May 12, 1971	43 [*]	2.9
	2 ^{**}	2.4
May 15, 1971	23 ^{***}	
* 0.5-m ² plot near low tide		
** 0.5-m ² plot near midtide		
*** 1.0-m plot near midtide		

d. Little-Neck Clams (Prototheca, Table A-8)

The initial sampling showed a mortality of Prototheca in sample area 1. The substrate of sample area 2 was not examined at that time but rather on May 15 the midtide area showed highest Prototheca density (26/m²; average shell length, 2.6 cm). There appeared to be persistent mortality in the Prototheca population at this time.

Approximately 10 percent of the clams taken were dead in situ, and the decomposing state of the tissue testified to their recent death.



Table A-8
PROTOTHECA SIZE DATA

Station	No.	Mean Shell Length (cm)
1 (near 1.0-ft tide height)	2	0.95
2 (lower-third tide zone)	26	2.6
3 (middle-third tide zone)	19	3.9
4 (upper-third tide zone)	12	3.8

e. Persistent Mortality

The sampling indicates extensive mortality during the week of April 26 to May 1, 1971. An important question is: What was the extent of mortality after May 1, 1971? It appears there was additional mortality in the Hemigrapsus population (at least until May 12). On May 15, 1971, a number of the rock crab Cancer productus were observed washed up at the low tide line—and these animals were only recently dead. One large sea star (Pisaster) was followed from April 28 to May 15. It was alive and appeared healthy on April 28; on May 12, it showed a loss of surface epithelium but was still alive; on May 15, it was dead. In the populations of Prototheca, clams were noticed freshly dead on May 15.



APPENDIX B

FIELD NOTES — ANACORTES SPILL SURVEY



APPENDIX B
FIELD NOTES — ANACORTES SPILL SURVEY

A. SIX TRAVERSE-TRANSECTS, GUEMES ISLAND

All transects started at mean high-water level and ran to a depth of approximately 10 m in channel. Samples were taken at mean high water (upper intertidal or UIT), middle intertidal (MIT), lower intertidal (LIT) or mean low water; 3 m or shallow subtidal (SST); and 10 m or deep subtidal (DST). At four separate stations, trawl and dredge were employed.

Samples taken at intertidal stations consisted of: (1) epifaunal inside $1/2\text{-m}^2$ quadrat; (2) random epifaunal; (3) infaunal $1/25\text{-m}^2$ inside $1/2\text{-m}^2$ quadrat and from within the $1/2\text{-m}^2$ quadrat; (4) bacteriological sediment; (5) interstitial water for hydrocarbons; and (6) sediment for hydrocarbons.

Photographs were taken of the traverse area and of each $1/2\text{-m}^2$ quadrat.

1. ST-I* (West End of Guemes Island)

- Time: 09:30 a.m. - 10:30 a.m. DST (daylight saving time), 9 May 1971

a. UIT, $1/2\text{-m}^2$ Quadrat

Bottle 1: epifauna — 2 Grapsus crabs dead; 22 Balanus (small) alive, 100 dead; 5 Mytilus alive; infauna — polychaete, few amphipods, and live crabs.

Bottle 2: infaunal sediment sample.

Bottle 3: interstitial water (hydrocarbon).

Bottle 4: sediment (hydrocarbon).

Bottle 5: bacteriology (sediment).

* ST = shore traverse



Initially — according to notes from a conversation with a Mrs. Moore, resident and owner of 150 ft of beach near the station traverse — oil covering the intertidal area persisted for about a week. Oil came in and out in globs (?) when the tide moved out. When oil hit the ducks (small diving ducks — mostly scaup and grebes), they died instantly (?). They disappeared or dove but did not reappear. Mrs. Moore claims that diving ducks are gone inasmuch as her pet gulls must be fed twice as much as before the spill when they took food from ducks. Oil went first to the east of her land and gradually moved west. Most of the duck kill was west of the ferry landing.

b. MIT

Bottle 6: random megafauna — mostly a Mytilus bed, few Cardium, few Thais, Acmaea, 1 dead Grapsus, 1 polychaete.

Bottle 7: $1/2\text{-m}^2$ quadrat epifaunal sample; rainbow sheen in pool.

Bottle 8: water sample for hydrocarbon.

Bottle 9: infauna from $1/25\text{ m}^2$; had slightly reducing sediments.

Bottle 10: bacteriology.

c. LIT

Photographs were obtained of large rainbow surrounding algae. Oil seeped out of mud at shore, and there was light sheen on interstitial water pools.

Faunal and Floral Observations: much Ulva, Fucus, smaller megafloa; several Cardium recently dead, all the same size (1-year class); Littorina and Thais dead; all Balanus dead.

Bottle 11: epifauna picked from $1/25\text{ m}^2$.

Bottle 12: bacteriology sediment.

Bottle 13: hydrocarbon water sample.

Bottle 14 (broken, not salvaged): random sample of epifauna (large invertebrates); Panope generosa squirting.



d. Subtidal Shallow (3 m) Directly Offshore

Bottle 15: Van Veen $1/25\text{-m}^2$ grab, including rocks, bryozoa, Fucus, lithothamnoids, and small algae.

Bottle 16: bottom-water hydrocarbon, 4 m.

e. Deep Subtidal (30 to 40 ft)

Dredge: 5 min; 1 Strongylocentrotus (urchin), algae Laminaria, Calliostoma (snail) shell (old), live limpets, Calyptraea, and Placanomia.

2. ST-II

a. UIT

Oil sheen was noted on the water 30 to 40 ft offshore as the traverse area was approached. There was the odor of oil along the beach, and there were 5 limpets Acmaea on the piling at the highest tide level. The $1/2\text{-m}^2$ quadrat had no epifauna, but there was some dead eel grass.

Bottle 17A: Van Veen $1/25\text{-m}^2$ infauna.

Bottle 18: bacteriology.

b. MIT

The $1/2\text{-m}^2$ quadrat epifauna sample consisted of a few isopods and one dead crab.

Bottle 19: epifauna from quadrat.

Bottle 20: infauna ($1/25\text{-m}^2$ grab).

Bottle 21: bacteriology — sediment.

c. LIT

The $1/2\text{-m}^2$ quadrat revealed brown organic debris coming from sand at shore and 1 large Pisaster starfish.



Bottle 22: hydrocarbon sediment sample.

Bottle 23: 1/25-m² grab for infauna.

Bottle 24: bacteriology sediment.

Bottle 25: hydrocarbon interstitial water.

Bottle 26: random sample collected from pilings; two zones demarked by two kinds of barnacles: upper zone, small barnacle; MIT, Mytilus dominant, with large species of barnacle only scattered; LIT, large barnacles dominant, few Mytilus; UIT, few limpets.

d. Subtidal Shallow (15 ft)

Bottle 27: 1/25-m² Van Veen.

Bottle 28: bottom water for hydrocarbons.

At 15 ft, there were large masses of Ulva and Laminaria but not much Fucus.

e. Deep Subtidal (35 to 45 ft)

Dredge (11:10 a.m. -11:14 a.m. DST): 3 Strongylocentrotus drobachiensis; polished gravel.

f. Deep Subtidal (extra) between ST II and ST III

This was trawled with a 15-ft otter trawl starting at 70 ft but mostly between 55 and 57 ft. The time was from 12:05 p.m. to 12:20 p.m. DST.

Bottle 29: 1 fish, 3 urchins, 2 species of spider crabs, hermit crabs, hydroids. The trawl hung up and pulled off straight up.

3. ST-III (East of Ferry Landing — Fence and Cut through Woods

a. UIT, 1/2-m² Quadrat

Bottle 30: random sample; odor of oil (more like crude).

Bottle 31: epifauna from 1/2-m² quadrat; strong oil smell; few snails, most of them dead; one dead limpet.



Bottle 32: sediment bacteriology.

Bottle 33: 1/25-m² Van Veen infaunal; silt layer beneath gravel.

Bottle 34: hydrocarbon sediment.

b. MIT, 1/2-m² Quadrat (Half in and Half out of Water)

There were several recently dead (2 hr) crabs. There were living and dead crabs under rocks but no decomposition.

Bottle 35: random epifaunal collection — many Littorina, very large barnacles, 1 Thais (snail); numerous dead crabs.

Bottle 36: epifaunal sample from quadrat — anemones, Littorina, large mass of dead eel grass, Lacuna (?), and limpets.

Bottle 37: hydrocarbon; interstitial water; slight sheen on surface.

Bottle 38: 1/25-m² Van Veen infauna; streaks of oil on top of sample in tub.

Bottle 39: bacteriology sediment.

c. LIT

This was under water; thus, grab and bottom water taken and photographs made. Oily sheen and rainbow were noted. The bottom was mostly algae and eel grass.

Bottle 40: hydrocarbon bottom water.

Bottle 41: 1/25-m² Van Veen — eel grass, one rock, algae.

d. Subtidal Shallow (25 ft — 8 ft of Tide)

Bottle 42: hydrocarbon bottom water.

Bottle 43: 1/25-m² Van Veen grab — bryozoa, lithothamnoids, rocks.



e. Deep Subtidal

Bottle 213: hydrocarbon bottom water.

Bottle 214: 1/25-m² Van Veen — small crab, 3 rocks, some red algae.

4. ST-IV

This was a weird shape of sediments on the cliff 1-3/4 mi from ST-I. Streaks of oil were on the water, and an odor of decomposition and diesel fuel was noted. Sheen and rainbows were at water's edge, and the stirring of sediment brought blobs of oil to the surface. Oil streaks appeared on the water.

a. UIT (Reducing Sediments)

Bottle 50: 1/2-m² quadrat epifauna included dead large crab, small live barnacles (dominant); subdominants were Mytilus, Littorina, polychaetes, few small live crabs. Reducing zone 1 cm deep; small bands of FeS.

Bottle 51: bacteria sediment.

Bottle 52: hydrocarbon sediment.

Bottle 53: 1/25-m² Van Veen infauna. Photograph taken of reducing zone.

Bottle 54: interstitial water — hydrocarbon.

b. MIT, 1/2-m² Quadrat

Here, there had been a recent crab kill.

Bottle 44: epifauna quadrat sample — barnacle alive, large Thais (snail), Mytilus, Littorina, anemone, worm tubes, dead oyster; rocks coated on bottom with oil.

Bottle 45: random epifauna — 19 dead crabs (recently) in 50-ft traverse.

Bottle 46: 1/25-m² Van Veen infauna.

Bottle 47: sediment hydrocarbon.

Bottle 48: sediment bacteria.

Bottle 49: water hydrocarbon.



c. LIT

- Time: 12:20 p.m. -1:00 p.m. DST

Bottle 116: random sample — starfish, strong acrid odor, large polychaete, blenny.

d. SST (23 ft)

Bottle 55: bottom-water hydrocarbon.

Bottle 56: photograph of eel grass through water.

e. DST

Bottle 57: 1/25-m² Van Veen — bryozoa, algae, lithothamnoids, clam shell, 2 types of limpets (Acmaea), Crepidula or Placania, Calyptraea, amphipod.

f. Extra-Deep Subtidal (DST)

The dredge was towed between ST-IV and ST-V at a depth of 30 ft. Between ST-IV and ST-V, there were streaks of oil on the surface. The time was 02:55 p.m. -03:10 p.m. DST. The dredge filled with clayey silt and algae, so it had to be washed out. Two jars were saved. There were thousands of amphipods.

Bottle 58: two jars, dredge sample.

5. ST-V

This was on the west side of a populated cove, with a fence at the edge of the cliff and a small clearing.

a. UIT

Bottle 61: random sample — Littorina lined up on small rocks even with tide level.

Bottle 62: 1/2-m² quadrat — no smell of oil; quadrat epifauna — dominant form, Littorina, barnacles (mostly small); no dead crabs.



Bottle 63: hydrocarbon sediment sample.

Bottle 64: hydrocarbon water sample.

Bottle 65: bacteriology sediment.

Bottle 66: 1/25-m² Van Veen infaunal sample.

b. MIT

Bottle 116A: random sample.

Bottle 117: 1/2-m² quadrat epifaunal sample — large hermit crab, algae (Ulva and another kind), tube worms on bottom of rocks, ophiuroid, sheen on interstitial water. Mostly algae, little fauna.

Bottle 118: sediment hydrocarbon sample.

Bottle 119: bacteriology sample.

Bottle 120: interstitial water hydrocarbon.

Bottle 121: 1/25-m² Van Veen infaunal sample.

c. LIT

- Time: 12:00 noon DST. Many dead crabs.

Bottle 110: random collection — several starfish, recently dead crabs, much oil at water's edge.

- 1/2-m² Quadrat: mostly rocks, part in water.

Bottle 111: epifaunal sample (putrid odor) — many dead crabs, many alive (perhaps outnumbering the dead ones); recently dead chitons; live Nassarius, blenny, small clams; hydrocarbons on bottom of rock and Fucus and Ulva on one large rock; dead limpets and algae decomposing; empty Callianassa tube and few amphipods.

Bottle 112: sediment hydrocarbons.

Bottle 113: bacteriological sample.

Bottle 114: interstitial water sample for hydrocarbons.

Bottle 115: 1/25-m² Van Veen infaunal sample.



d. SST

Bottle 122: $1/25\text{-m}^2$ Van Veen infaunal.

Bottle 67: bottom-water sample for hydrocarbon.

Bottle 68: $1/25\text{-m}^2$ bottom grab Van Veen for infauna.

e. DST

Bottle 59: $1/25\text{-m}^2$ Van Veen infauna grab.

Bottle 60: bottom-water sample for hydrocarbon.

6. ST-VI

This was just west of the southeastern tip of Guemes Island by a large stump. At high tide, there were many large limpets as well as large Littorina sitkana.

a. UIT

Bottle 71: bacteriological sample.

● $1/2\text{-m}^2$ Quadrat: pebbly beach

Bottle 72: epifaunal sample — no animals; several dead crabs. No evidence of oil. $1/25\text{-m}^2$ Van Veen infaunal sample for No. 72.

Bottle 73: small Mytilus, barnacles.

b. MIT

Bottle 105: random sample (some from small tidal pool). Strong sheen and odor from pool.

● $1/2\text{-m}^2$ quadrat: no $1/25\text{-m}^2$ infauna (?)

Bottle 106: epifaunal sample — dead crabs, considerable Ulva, and barnacles scarce (although areas of missing barnacles common). Oil odor on rocks. Limpets alive and several dead, with 1 decomposing; 1 to 10 living to dead barnacles; 20 to 30 live crabs; some polychaetes; 1 Mytilus; many dead crabs; dead barnacles under large rock.



Bottle 107: sediment hydrocarbon sample.

Bottle 108: bacteriology sample.

Bottle 109: $1/25\text{-m}^2$ Van Veen for infaunal sample.

c. LIT

- Time: 11:20 a.m. DST

Bottle 101: random sample — many dead crabs on beach and not much life under rocks (although a few tunicates on top of rocks).

- $1/2\text{-m}^2$ quadrat

No Number (?): $1/25\text{-m}^2$ infauna (not taken).

Bottle 102: large holothurian (Stichopus) and starfish (Pisaster), large polychaete (Nereis), freshly killed Nassarius, numerous amphipods, isopods, barnacles, small clams, live crabs, 1 limpet. Rainbow sheen under rocks; strong hydrocarbon odor; oil seeps from sediments. Rocks remarkably clean of animals; seems to be high-impact area. Beach in poor condition for animals. Epifauna in quadrat.

Bottle 103: sediment hydrocarbon.

Bottle 104: bacteriology.

d. SST (10 ft)

Bottle 74: hydrocarbon water sample.

Bottle 75: $1/25\text{-m}^2$ Van Veen infaunal sample — large rock, algae.

e. DST (42 ft)

Bottle 69: $1/25\text{-m}^2$ Van Veen infaunal sample — shelly gravelly mud.

Bottle 70: hydrocarbon water sample.



Just offshore ST-VI subtidally in 12- to 14-ft depths, oil bubbles floated to the surface from eel grass bed, leaving rainbow sheen on the surface. Globbs could be observed leaving the mud sediment for the surface.

B. HUCKLEBERRY ISLAND

Upon arrival at shore, we noted oily sheen at the shoreline. Starfish, Pisaster ochraceous, were abundant; several large holothurians, Stichopus, were observed and photographed at the shoreline.

1. ST-VII

- Time: 10:00 a.m. DST, 11 May 1971

a. UIT

Bottle 78: $1/2\text{-m}^2$ quadrat epifauna — 5 live small Balanus, several Littorina, oily odor, dead crab, 1 small clam.

Bottle 79: random-sample epifauna — very sparse.

Bottle 80: bacteriology.

Bottle 81: sediment hydrocarbons.

Bottle 81A: $1/25\text{-m}^2$ Van Veen grab for infauna.

b. MIT

Bottle 82: $1/2\text{-m}^2$ quadrat — some small barnacles, a few dead small Littorina, large dead crab, algae, live crab, small amounts of Fucus attached to rocks, shells of limpets. No odor of hydrocarbons.

Bottle 83: $1/25\text{-m}^2$ Van Veen grab for infauna.

Bottle 84: random-sample of epifauna — many living and dead crabs.

Bottle 85: bacteriology sample.

Bottle 86: hydrocarbon sediment sample.



c. LIT

Bottle 87: $1/2\text{-m}^2$ quadrat (partly within a tidal pool) — epifauna: Fucus on rocks; dead crabs (panopeidae). Bad oily sheen with diesel odor, reducing (black FeS) conditions prevalent, suggesting sulfate reducing bacteria. Small barnacles present, live crab, polychaete (worm). Not as rich as most tide pools. Additional animals under rocks — turritid snail, small amphipods, and one ophiuroid (brittle starfish).

Bottle 88: $1/25\text{-m}^2$ Van Veen infaunal grab.

Bottle 89: random sample included Dungeness crab.

No Bottles: water hydrocarbon, bacteriology, and sediment hydrocarbon (where??).

d. SST (10 to 12 ft)

Bottle 117A: hydrocarbon water sample.

No Bottle: bottom Van Veen infauna sample (where?).

e. DST (25 ft)

Bottle 76: $1/25\text{-m}^2$ Van Veen grab infauna.

Bottle 77: bottom-water hydrocarbon sample.

C. COVE ON SADDLEBAG ISLAND

1. ST-VIII

a. UIT

- Time: 2:20 p.m. DST

Bottle 133 (broken, not salvaged): random epifaunal sample — nothing alive on the surface but a few grapsoid crabs.

In the $1/2\text{-m}^2$ quadrat, there were no live epifauna.



Bottle 134: 1/25-m² Van Veen infaunal grab. Strong diesel smell, slightly reducing sediments (decomposition).

Bottle 135: sediment hydrocarbon sample.

Bottle 136: bacteriology sample.

b. MIT

- Time: 2:15 p.m. DST

Bottle 127: random epifaunal sample. Sediment slightly reducing (H₂S and black FeS color); water trapped in cove, and oil was concentrated there, being released at shoreline with moving tide.

Bottle 128: 1/25-m² Van Veen infaunal grab.

Bottle 129: 1/2-m² quadrat epifaunal sample — large number of large live barnacles; many small crabs, Mytilus, sick or narcotized snails, 5 live crabs; under rocks, oil zone with diesel smell and black decomposition (reducing) zone; 3 live crabs, 2 snails, several tunicates (Molgula), dead crabs, recently dead barnacles; fine green algae on rocks. Bottom of rock had dead appearance.

Bottle 130: interstitial water hydrocarbon sample.

Bottle 131: bacteriological sample.

Bottle 132: sediment hydrocarbon sample.

c. LIT

- Time: 10:30 a.m. DST

Bottle 90: 1/25-m² Van Veen grab for infauna.

The 1/2-m² quadrat included part of the tidal pool.

Bottle 91: epifaunal sample — nothing alive except algae and some eel grass; few Macoma shells; oily sheen on flats; sick and dying eel grass.

Bottle 92: sediment hydrocarbon sample.

Bottle 93: random epifaunal sample — occasional live Cardium (cockle), polychaetes.



Bottle 94: interstitial water hydrocarbon sample.

Bottle 95: bacteriological sample.

Bottle 96: snails (Nassarius) killed in tidal pool. Photographed with oily sheen and dead snails.

d. SST (10 to 12 ft)

- Time: 02:10 p.m. DST.

Bottle 125: bottom-water hydrocarbon sample.

Bottle 126: 1/25-m² Van Veen infaunal grab sample — rainbows, oily sheen; many dead polychaetes (worms) in water.

e. DST (25 ft)

Bottle 123: 1/25-m² Van Veen infaunal grab sample — oily sheen on water and on sediment in grab.

Bottle 124: hydrocarbon bottom-water sample.

Bottle 151: 14-ft otter trawl 30 ft deep in circle in cove for approximately 7 min. Catch included vegetation and Dungeness crabs.

D. HAT ISLAND (SMALL COVE ON SOUTH SIDE)

1. ST-IX

a. UIT

Bottle 144: random epifaunal sample.

- 1/2-m² Quadrat

Bottle 145: epifaunal sample — many small snails (Littorina), few barnacles, many crabs, Mytilus, limpets, and larger snails.

Bottle 146: hydrocarbon interstitial water samples.

Bottle 147: sediment hydrocarbon samples.

Bottle 148: bacteriological sample.

Bottle 149: 1/25-m² Van Veen infaunal sample.



b. MIT

Bottle 139 (broken, not salvaged): random epifaunal sample — limpets and eels.

Bottle 139A: 1/25-m² Van Veen grab infaunal sample.

● 1/2-m² Quadrat

Bottle 140: epifaunal sample — numerous barnacles, 75 to 100 live crabs, many Littorina, Lacuna (snails), many type of amphipods, many snails, several Mytilus, 9 limpets, eels, large green amphipod, large Idoteid isopod, very rich fauna.

Bottle 141: interstitial water hydrocarbon sample.

Bottle 142: bacteriological sample.

Bottle 143: sediment hydrocarbon sample.

c. LIT (Large Algae Bed)

● 1/2-m² Quadrat

Bottle 97: large amounts of Fucus and red algae (Rhodophyta), 4 small crabs, 2 large polychaetes, large crab, serpulid worms, small amphipods, small turbinid gastropod, isopods, large hermit crab. No evidence of oil or other hydrocarbons.

Bottle 98: random epifaunal sample.

Bottle 99: sediment hydrocarbon sample.

Bottle 100: bacteriological sample.

d. SST (10 ft)

Bottle 150: bottom-water hydrocarbon sample.

No Bottle: 1/25-m² Van Veen (where?).

e. DST (30 ft)

Bottle 137: bottom-water hydrocarbon sample.

Bottle 138: 1/25-m² Van Veen grab for infauna.



E. ORCAS ISLAND, DEER POINT AREA

The following describes control traverses made on 11 May 1971.

1. ST-X

The location was a small cove adjacent to the beach in front of a small settlement. There was some fresh-water input 500 yd west of the traverse.

a. UIT, 1/2-m² Quadrat

Bottle 154: epifaunal sample — numerous crabs, limpet, a different type of barnacle, many gammarid amphipods, 1 Mytilus, 2 species of small gastropods, 2 dead cancrroid-like crabs, and 1 Dungeness. Fauna very rich and varied.

Bottle 155: random epifaunal sample — varied high-standing crop; 3 types of crabs and limpets.

Bottle 156: interstitial water sample for hydrocarbons.

Bottle 157: bacteriological sample.

Bottle 158: sediment hydrocarbon sample.

Bottle 159: 1/25-m² Van Veen grab for infauna.

b. MIT, 1/2-m² Quadrat (Finer Sediment)

Bottle 160: epifaunal sample — snails covering sediment, limpets, large species of barnacle, several crabs, Mytilus.

Bottle 161: random epifaunal sample. Diversity lower at MIT than at UIT.

Bottle 162: interstitial water for hydrocarbon.

Bottle 163: bacteriological sample.

Bottle 164: sediment hydrocarbon sample.

Bottle 165: 1/25-m² Van Veen infaunal grab sample.

c. LIT

Bottle 166: random epifaunal sample — intermediate size oysters on rocks; slightly different kinds of intertidal fauna.



- 1/2-m² Quadrat (Mostly Infauna)

Bottle 167: epifaunal sample — tunicates, tube-making amphipods, Ulva, many amphipods, possibly mites.

Bottle 168: sediment hydrocarbon sample.

Bottle 169: 1/25-m² Van Veen infaunal grab.

Bottle 170: bacteriological sample.

Bottle 171: interstitial water sample for hydrocarbons.

d. SST (10 ft)

- Time: 10:55 a.m. DST

Bottle 152: hydrocarbon bottom-water sample.

Bottle 153: 1/25-m² Van Veen grab for infauna.

e. DST (30 ft)

Bottle 172: bottom-water hydrocarbon sample.

Bottle 173: 1/25-m² Van Veen grab for infauna.

2. ST-XI

The area was a small cove 200 yd west of Deer Point at the foot of a large mansion.

- Time: 11:50 a.m. DST

a. UIT

Bottle 174: random epifaunal sample. Some supertidal pools among rocks, with isopods common.

- 1/2-m² Quadrat

Large barnacles were adjacent to the quadrat, and there was coarse gravel sediment.



Bottle 175: epifaunal sample — several Littorina, amphipod, 1 small and 1 large crab, 1 limpet shell. No interstitial water.

Bottle 176: 1/25-m² Van Veen infaunal grab.

Bottle 177: bacteriological sample.

Bottle 178: sediment hydrocarbon sample.

b. MIT

Bottle 179: random epifaunal sample. Intertidal pools have high diversity and populations of invertebrates and fish.

● 1/2-m² Quadrat (on Steep Slope)

Bottle 180: epifaunal sample — algae (Fucus), ghost shrimp hole (Upogebia), many crabs of 2 species, 2 dead Dungeness crabs, few live barnacles, many limpets, 1 live pelecypod (clam), 1 tube worm on bottom of rock. No interstitial water for sample.

Bottle 181: bacteriological sample.

Bottle 182: sediment hydrocarbon sample.

Bottle 183: 1/25-m² Van Veen infaunal sample.

c. LIT

Bottle 185: random epifaunal sample.

● 1/2-m² Quadrat

Bottle 184: epifaunal sample — Muricid snail shell, Ulva, limpet, many amphipods, many polychaete worms, two types of crabs, Mytilus, green amphipod, and large Venerid clam.

Bottle 186: bacteriological sample.

Bottle 187: sediment hydrocarbon sample.

Bottle 188: 1/25-m² Van Veen infaunal grab (slight reducing zone 1 cm deep).



d. SST

Bottle 190: bottom-water hydrocarbon sample.

Bottle 211: $1/25\text{-m}^2$ Van Veen infaunal sample.

e. DST (15 to 20 ft)

• Time: 12:40 p.m. DST

Bottle 189: bottom-water hydrocarbon sample

Bottle 212: $1/25\text{-m}^2$ Van Veen infaunal sample.

f. Extra Offshore Grab Sample (20 ft)

This was taken between ST-X and ST-XI.

Bottle 191: $1/25\text{-m}^2$ Van Veen for infauna.

3. ST-XII

This area was a dry well-drained gravel and boulder beach at a large cove on the northeast side of Deer Point.

Bottle 203: random epifaunal sample over 150 yd. No life except on one rock which had many limpets and a few barnacles.

a. UIT, $1/2\text{-m}^2$ Quadrat

Bottle 202: barren; no life in quadrat. Drainage too good.

Bottle 204: $1/25\text{-m}^2$ Van Veen infaunal grab.

Bottle 205: bacteriological sample.

Bottle 206: sediment hydrocarbon sample.

b. MIT

Bottle 198: random epifaunal sample. Appeared to be a naturally stressed environment due to poor retention at interstitial water.



- 1/2-m² Quadrat

Bottle 199: epifaunal sample — dead amphipods, live worm, many barnacles.

Bottle 200: sediment hydrocarbon sample.

Bottle 200A: bacteriological sample.

Bottle 201: 1/25-m² Van Veen grab sample.

c. LIT

- Time: 01:30 p.m. DST

This area featured small boulders and rocks.

Bottle 192: random epifaunal sample — large worms under rocks. Not very productive and has odor of decomposition.

- 1/2-m² Quadrat (Partially in Water)

Bottle 193: epifaunal sample — 8 large and small limpets, algae (mostly Fucus), barnacles, polychaete worms in sediment.

Bottle 194: bacteriological sample.

Bottle 195: hydrocarbon water sample.

Bottle 196: 1/25-m² Van Veen infaunal grab sample.

Bottle 197: sediment hydrocarbon sample.

d. SST (10 ft)

Bottle 207: bottom-water hydrocarbon sample.

Bottle 208: 1/25-m² Van Veen infaunal grab.

e. DST (20 to 30 ft)

Bottle 209: bottom-water hydrocarbon sample.

Bottle 210: 1/25-m² Van Veen infaunal grab.



F. PADILLA BAY

The Padilla Bay traverses were made late on the afternoon of 11 May 1971.

1. ST-XIII

This was on a boulder and cobble beach on the west side of Padilla Bay 1/2 mi south of March Point. High tide precluded MIT and LIT traverses.

a. UIT (No Random Sample)

- 1/2-m² Quadrat (Half in Water; Tide Rising)

Bottle 213A: epifauna — snails (Lacuna, Littorina), live barnacles, very many amphipods, 4 small Mytilus, bryozoa (Bugula), limpets. Tan foamy material floating on water along shore. No sheen on water.

Bottle 214A: bacteriological sample.

Bottle 215: sediment hydrocarbon sample.

Bottle 216: 1/25-m² Van Veen grab infaunal sample.

Bottle 217: hydrocarbon water sample.

Parker's camera was inundated by the tide, so the quadrat was photographed with Watson's camera.

Traverses taken in Padilla Bay on the tidal flats and eelgrass beds on 11 May 1971 showed Dungeness crabs and oysters.

G. OFFSHORE TRAVERSES

1. XIV

Bottle 218: bottom-water hydrocarbon sample.

Bottle 219: 15-ft otter trawl for nekton.

Bottle 220: bacteriological sample.

Bottle 221: 1/25-m² Van Veen infaunal grab.

Bottle 222: plankton tow for zooplankton and phytoplankton.



2. XV

- Bottle 223: bottom-water hydrocarbon sample.
Bottle 224: 15-ft otter trawl for nekton.
Bottle 225: bacteriological sample.
Bottle 226: 1/25-m² Van Veen infaunal grab.
Bottle 227: plankton tow for zooplankton and photoplankton.

3. XVI

- Bottle 228: bottom-water hydrocarbon sample.
Bottle 229: 15-ft otter trawl for nekton.
Bottle 230: bacteriological sample.
Bottle 231: 1/25-m² Van Veen infaunal grab.
Bottle 232: plankton tow for zooplankton and phytoplankton.

H. LUMMI ISLAND

Shore traverses were made on the northern part of Lummi Island on 12 May 1971 at 12:45 p.m. DST at the sites of reported faunal kills.

1. ST-XVII

This site of heavy Euphausid and Mysid kill after the spill is located on the west side of Lummi Island, second cove from the northern tip.

a. UIT (Medium-Grain-Sized Sand Beach)

Bottle 279: random epifauna — amphipods and isopods under logs extremely abundant.

• 1/2-m² Quadrat

This was barren of epifauna, so no sample was taken.

- Bottle 280: bacteriological sample.
Bottle 281: 1/25-m² Van Veen infaunal grab.
Bottle 282: sediment hydrocarbon sample.



b. MIT

Bottle 285: random epifaunal from isolated rock. Sheltered or landward side; productive with hundreds of newly settled barnacles. Seaward side of rock barren.

- $1/2\text{-m}^2$ Quadrat

This consisted of coarse gravel, with some sand underneath and a stressed beach.

Bottle 283: epifaunal sample — 1 recently dead crab, couple of small Littorina, 1 worm, and washed — in Fucus (algae).

Bottle 284: bacteriological sample.

Bottle 287: sediment hydrocarbon sample.

Bottle 288: $1/25\text{-m}^2$ Van Veen infaunal sample — worm observed.

c. LIT (Cobbles and Algae)

Bottle 289: random epifaunal sample — 1 live Dungeness crab, many eels and cling (?) fish (gobies or blennies). No evidence of ever having a large barnacle population.

- $1/2\text{-m}^2$ Quadrat (Half in Water)

Bottle 290: epifaunal sample — 4 limpets, various kinds of algae, 2 barnacles. Not as rich as most LIT areas.

Bottle 291: hydrocarbon water sample.

Bottle 292: sediment hydrocarbon sample.

- No $1/25\text{-m}^2$ Van Veen (?) infauna.

d. SST (10 ft)

- Time: 12:45 p.m. DST

Bottle 275: $1/25\text{-m}^2$ Van Veen infaunal grab.

Bottle 276: bottom-water hydrocarbon sample.



e. DST (20 to 30 ft)

Bottle 277: $1/25\text{-m}^2$ Van Veen infaunal grab.

Bottle 278: bottom-water hydrocarbon sample.

2. ST-XVIII

• Time: 01:20 p.m. DST

The area, a cove on the east side of Lummi Island, north of the ferry, was the site of a possible crab kill and was fairly densely populated.

a. UIT (Cobble Beach)

Bottle 308: random epifaunal sample.

• $1/2\text{-m}^2$ Quadrat

Bottle 309: epifaunal sample — dead algae and 1 crab claw.

Bottle 310: $1/25\text{-m}^2$ Van Veen infaunal grab. Rocks with thin layer of sand; barren.

Bottle 311: bacteriological sample.

Bottle 312: sediment hydrocarbon sample.

b. MIT

Bottle 306: random epifaunal sample. Very little epifauna but fairly rich infauna.

• $1/2\text{-m}^2$ Quadrat

Bottle 302: epifaunal sample. Fine-grained sand; few pebbles and shell. Some algae; only a polychaete worm.

Bottle 303: interstitial water for hydrocarbons.

Bottle 304: bacteriological sample.

Bottle 305: sediment hydrocarbon sample.

Bottle 307: $1/25\text{-m}^2$ Van Veen infaunal sample.



c. LIT

This sand flat, with tide pools and a few cobbles, had many amphipod sand tubes.

Bottle 301: random epifaunal sample — 1 dead crab.

● 1/2-m² Quadrat

Bottle 297: epifaunal sample — small worms, many fecal pellets, amphipods, and some Ulva (algae).

Bottle 298: hydrocarbon water sample.

Bottle 298A: 1/25-m² Van Veen grab for infauna.

Bottle 299: bacteriological sample.

Bottle 300: sediment hydrocarbon sample.

d. SST (8 to 10 ft)

Bottle 293: bottom-water sample for hydrocarbon.

Bottle 294: 1/25-m² Van Veen infaunal grab sample.

e. DST (20 to 30 ft)

Bottle 295: bottom-water sample for hydrocarbon.

Bottle 296: 1/25-m² Van Veen grab for infauna.

3. Notes from Lummi Indians

The following information was taken in the form of notes from Lummi Indians at their tribal-council headquarters.

Following the spill on 26 April 1971, slicks were sighted on the northwest side of Lummi Island along the beach on 27 April. On 28 April, oil was noted at the mainland ferry landing. On 1 May, a shrimp kill (Euphausids and Mysids) was observed as a 20-ft 1-in. -thick mass on the shore on the northwest side of Lummi. A biologist (Steven Steele), who was working on a Lummi Indian maraculture project, stated that both areas where traverses were occupied are poor in fauna (low productivity). This may be due to tidal phenomena and high winter exposure.



APPENDIX C

TOTAL COUNTS OF MAJOR TAXA (DIVERSITY), MEIOFAUNA



APPENDIX C
TOTAL COUNTS OF MAJOR TAXIA (DIVERSITY), MEIOFAUNA

Traverse	Zone	Type Sample	Taxa	No.
I	UIT	Quadrat	Polyplacophora	1
			Gastropoda	2
			Pelecypoda	2
			Nematoda	55
			Polychaeta	2
			Cirripedia	2
			Grapsidae	12
I	UIT	Van Veen	Nematoda	4
			Acarida	1
			Cirripedia larva	1
I	MIT	Random	Nematoda	8
			Pelecypoda	2
			Polyplacophora	1
			Isopoda	35
			Gastropoda	4
			Decapoda	1
I	MIT	Quadrat	Gastropoda	1
			Cirripedia	2
			Pelecypoda	8
			Decapoda	1
I	MIT	Van Veen	Nematoda	71
			Copepoda	1
			Polychaeta	1
I	LIT	Van Veen	Nematoda	1
			Pelecypoda	1
			Copepoda	2
			Decapoda zoea	2
I	LIT	Quadrat	Nematoda	1
			Gastropoda	1
			Copepoda	2
			Decapoda larvae	2
I	SST	Van Veen	Hydrozoa	present
			Nematoda	25
			Gastropoda	8
			Nudibranchia	1
			Polychaeta	44



Traverse	Zone	Type Sample	Taxa	No.
I	SST	Van Veen	Acarida (mites)	1
			Foraminifera	1
			Crustacea larva	1
			Copepoda	309
			Ostracoda	5
			Cirripedia larvae	2
			Amphipoda	80
			Isopoda	1
			Echinoidea larva	1
			Decapoda	1
			Unknown	2
I	DST	Dredge	Ectoprocta	70
			Cirripedia	1
			Gastropoda	2
			Echinoidea	1
			Polychaeta	35
			Decapoda	2
II	UIT	Van Veen	Nematoda	34
			Cumacea	1
			Polychaeta	3
			Decapoda zoea	82
			Copepoda	72
			Crangonidae	1
			Cirripedia larvae	314
II	MIT	Quadrat	Gastropoda	1
			Amphipoda	3
			Copepoda	3
			Decapoda	1
II	MIT	Van Veen	Nematoda	1540
			Copepoda	13
			Sipunculoidea	1
			Ostracoda	2
			Oligochaeta	8
			Cirripedia larvae	54
			Polychaeta	50
			Isopoda	6
			Acarida	1
			Decapoda larvae	2
			Foraminifera	3



Traverse	Zone	Type Sample	Taxa	No.
II	LIT	Van Veen	Ostracoda	12
			Nematoda	29
			Cumacea	4
			Oligochaeta	2
			Isopoda	8
			Polychaeta	1
			Cirripedia larva	1
			Copepoda	18
			Decapoda zoea	1
II	LIT	Quadrat	Gastropoda	6
			Copepoda	28
			Pelecypoda	16
			Cirripedia	28
II	SST	Van Veen	Nematoda	91
			Isopoda	2
			Gastropoda	9
			Tanaidacea	7
			Polychaeta	63
			Echinoidea larva	1
			Copepoda	112
			Algae	present
			Amphipoda	1
II	DST	Dredge	Foraminifera	120
			Scyphozoa	1
			Cirripedia	152 *
			Hydrozoa	colonies
			Amphipoda	6
			Nematoda	1
			Isopoda	3
			Ectoprocta	colonies **
			Echinoidea	4
			Nudibranchia	4
			Decapoda zoea	150
			Polychaeta	10
			Algae	present
			Copepoda	97
			Foraminifera	2
III	UIT	Random	Gastropoda	4
			Amphipoda	1

* 2

** Several



Traverse	Zone	Type Sample	Taxa	No.
III	UIT	Random	Copepoda	1
			Decapoda	14
			Cirripedia larvae	4
			Algae	present
III	UIT	Quadrat	Gastropoda	9
			Decapoda	11
			Cirripedia	5
			Polychaeta	3
			Nematoda	1
III	UIT	Van Veen	Nematoda	104
			Cirripedia larvae	21
			Gastropoda	5
			Isopoda	2
			Polychaeta	3
			Decapoda	2
			Acarida	2
			Decapoda larvae	23
			Copepoda	7
			Algae	present
			Ostracoda	19
III	MIT	Random	Gastropoda	23
			Cirripedia	5
			Pelecypoda	4
			Decapoda	4
			Polychaeta	6
			Copepoda	2
			Nematoda	3
			Cirripedia larvae	16
III	MIT	Quadrat	Anthozoa	3
			Cirripedia	1
			Ectoprocta	3
			Gastropoda	14
			Algae	present
			Nudibranchia	4
			Pelecypoda	2
			Hydrozoa	1
			Polychaeta	3
			Nematoda	29
			Copepoda	17
			Cirripedia larvae	152
			Cumacea	1



Traverse	Zone	Type Sample	Taxa	No.
III	MIT	Van Veen	Nemertea	2
			Cumacea	2
			Nematoda	47
			Isopoda	1
			Gastropoda	2
			Tanaidacea	1
			Pelecypoda	2
			Decapoda	1
			Copepoda	46
			Algae	present
			Cirripedia	18
III	LIT	Van Veen	Nematoda	6
			Ostracoda	5
			Gastropoda	14
			Cirripedia larvae	7
			Pelecypoda	1
			Isopoda	15
			Polychaeta	10
			Tanaidacea	1
			Copepoda	28
			Decapoda larva	1
			Foraminifera	7
III	SST	Van Veen	Ectoprocta	colonies [*]
			Isopoda	1
			Polyplacophora	2
			Tanaidacea	1
			Polychaeta	1
			Nematoda	18
			Ostracoda	5
			Copepoda	22
			Cirripedia larvae	5
			Algae	present
III	DST	Van Veen	Hydrozoa	2
			Polychaeta	16
			Ectoprocta	10
			Cirripedia	2
			Polyplacophora	2
			Echinoidea larvae	7

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Traverse	Zone	Type Sample	Taxa	No.
III	DST	Van Veen	Gastropoda	2
			Decapoda	1
			Nematoda	22
			Amphipoda	3
			Copepoda	67
			Tanaicae	2
			Amphipoda	3
			Cirripedia larva	1
			Ostracoda	4
III	DST	Trawl	Hydrozoa	17
			Cirripedia	71
			Nematoda	5
			Amphipoda	82
			Ectoprocta	2
			Isopoda	1
			Polyplacophora	1
			Decapoda	11
			Gastropoda	12
			Echinoidea	5
			Nudibranchia	1
			Osteichthyes	1
			Polychaeta	9
			Porifera	2
			Copepoda	23
			Foraminifera	44
IV	UIT	Quadrat	Nematoda	1
			Polychaeta	1
			Pelecypoda	6
			Decapoda	5
IV	UIT	Van Veen	Nemertea	27
			Ostracoda	10
			Nematoda	2703
			Cirripedia larvae	9
			Pelecypoda	2
			Amphipoda	1
			Sipunculoidea	4
			Isopoda	2
			Polychaeta	70
			Decapoda	2
			Acarida	1
			Copepoda	95
			Foraminifera	5
			Algae	present



Traverse	Zone	Type Sample	Taxa	No.
IV	MIT	Quadrat	Nematoda	9
			Copepoda	4
			Gastropoda	9
			Ostracoda	2
			Pelecypoda	1
			Polychaeta	17
			Acarida	2
IV	MIT	Random	Nematoda	29
			Cirripedia	5
			Pelecypoda	7
			Isopoda	1
			Polychaeta	3
			Decapoda	1
			Copepoda	5
			Tanaidacea	1
			Ostracoda	2
			Decapoda larvae	3
IV	MIT	Van Veen	Nematoda	1000
			Cirripedia larvae	85
			Gastropoda	3
			Amphipoda	7
			Pelecypoda	18
			Cumacea	2
			Sipunculoidea	1
			Isopoda	4
			Polychaeta	193
			Tanaidacea	2
			Acarida	5
			Decapoda zoea	20
			Copepoda	62
			Ostracoda	44
			Decapoda	1
			Algae	present
IV	LIT	Random *	Anthozoa	2
			Polychaeta	5
			Gastropoda	4
			Decapoda	5
			Pelecypoda	6
			Copepod	present

* Incomplete



Traverse	Zone	Type Sample	Taxa	No.
IV	DST	Van Veen [*]	Ectoprocta	100
			Polychaeta	17
			Polyplacophora	1
			Amphipoda	13
			Gastropoda	16
			Decapoda	5
			Pelecypoda	6
			Ophiuroidea	3
			Nematoda	38
			Copepoda	82
			Cumacea	2
V	UIT	Random	Nematoda	1
			Ostracoda	5
			Gastropoda	14
			Decapoda	5
			Pelecypoda	1
V	UIT	Van Veen	Nematoda	9
			Ostracoda	2
			Polychaeta	2
			Cirripedia	12
			Acarida	1
			Copepoda	1
			Decapoda	1
			Algae	present
V	UIT	Quadrat	Nematoda	20
			Cirripedia	2
			Gastropoda	19
V	MIT	Random	Nematoda	52
			Cumacea	1
			Pelecypoda	10
			Decapoda	5
			Polychaeta	26
			Diptera	1
			Ostracoda	1
			Asteroidea	2
			Cirripedia	3
			Polyplacophora	1
			Copepoda	4
			Gastropoda	2
			Holothruoidea	1
			Algae	present

^{*} Incomplete



Traverse	Zone	Type Sample	Taxa	No.
V	MIT	Quadrat	Nematoda	40
			Polychaeta	10
			Copepoda	80
			Cirripedia larvae	4
			Nudibranchia	4
			Cumacea	2
			Amphipoda	2
			Isopoda	1
V	MIT	Van Veen	Turbellaria	28
			Ostracoda	75
			Nematoda	22,366
			Cirripedia	1
			Gastropoda	10
			Amphipoda	19
			Pelecypoda	17
			Cumacea	94
			Sipunculoidea	18
			Isopoda	4
			Oligochaeta	55
			Tanaidacea	5
			Polychaeta	219
			Insecta	2
			Copepoda	497
			Cirripedia larvae	57
V	LIT	Random	Anthozoa	73
			Cirripedia	8
			Polyplacophora	2
			Cumacea	1
			Pelecypoda	1
			Decapoda	10
			Sipunculoidea	1
			Asteroidea	3
			Polychaeta	2
			Copepoda	2
			Amphipoda	1
			Egg cases	
V	LIT	Quadrat	Nematoda	3
			Amphipoda	1
			Gastropoda	4
			Ophiuroidea	1
			Polychaeta	3
			Asteroidea	1



Traverse	Zone	Type Sample	Taxa	No.
V	LIT	Quadrat	Acarida	3
			Decapoda	23
			Copepoda	74
			Cirripedia	10
			Osteichthyes	1
			Algae	present
V	LIT	Van Veen	Foraminifera	113
			Cirripedia	40
			Nematoda	1244
			Isopoda	9
			Pelecypoda	2
			Decapoda	6
			Sipunculoidea	2
			Acarida	61
			Polychaeta	79
			Decapoda zoea	1
			Copepoda	1068
			Ostracoda	39
			Harpacticoidea	7
			Turbellaria	5
			Tanaidacea	1
			Oligochaeta	4
			Eggs	present
V	SST	Van Veen	Nematoda	500
			Pelecypoda	2
			Gastropoda	4
			Decapoda	1
V	DST	Van Veen	Nematoda	24
			Polychaeta	14
			Gastropoda	3
			Amphipoda	165
			Pelecypoda	4
			Tanaidacea	2
			Sipunculoidea	1
			Decapoda	1
VI	UIT	Van Veen	Foraminifera	4
			Cirripedia larvae	3
			Nemertea	2
			Isopoda	22
			Nematoda	34
			Polychaeta	14
			Ostracoda	1



Traverse	Zone	Type Sample	Taxa	No.
VI	UIT	Van Veen	Acarida	3
			Decapoda	1
			Copepoda	5
			Eggs	present
VI	UIT	Random	Gastropoda	3
			Decapoda	7
			Pelecypoda	2
			Polyplacophora	11
VI	MIT	Random	Pelecypoda	1
			Decapoda	5
			Nematoda	2
VI	MIT	Quadrat	Pelecypoda	1
			Decapoda	9
			Polychaeta	25
			Cirripodea	3
			Copepoda	1
VI	MIT	Van Veen	Foraminifera	present
			Copepoda	95
			Nemertea	80
			Ostracoda	17
			Nematoda *	287
			Cirripedia	50
			Gastropoda	2
			Pelecypoda	3
			Isopoda	5
			Acarida	68
			Crustacean larvae	56
			Algae (diatoms)	present
VI	LIT	Random	Polychaeta	1
			Decapoda	5
			Cirripedia	3
			Cirripedia larva	1
			Nematoda	3
			Decapoda larvae	2
			Gastropoda	7
			Copepoda	14

* Larva and juveniles



Traverse	Zone	Type Sample	Taxa	No.
VI	LIT	Quadrat	Foraminifera	10
			Cumacea	1
			Tubellaria	6
			Decapoda	3
			Gastropoda	2
			Asteroidea larvae	11
			Nudibranchia	1
			Holothuroidea	2
			Copepoda	38
			Ostracoda	2
			Amphipoda	4
			Algae	present
			Egg cases	present
VI	SST	Van Veen	Nematoda	204
			Copepoda	2488
			Gastropoda	4
			Nudibranchia	4
			Polychaeta	28
			Cirripedia larvae	8
VII	UIT	Random	Cirripedia	10
VII	UIT	Quadrat	Gastropoda	6
			Cirripedia	2
			Pelecypoda	1
			Nematoda	3
			Copepoda	7
VII	UIT	Van Veen	Nematomorpha	26
			Ostracoda	10
			Gastropoda	1
			Cirripedia	8
			Oligochaeta	4
			Isopoda	1
			Polychaeta	1
			Tanaidacea	3
			Acarida	5
			Decapoda	1
			Copepoda	54
			Decapoda larvae	2
			Foraminifera	6



Traverse	Zone	Type Sample	Taxa	No.
VII	MIT	Random	Pelecypoda	4
			Decapoda	5
			Gastropoda	1
			Holothuroidea	1
			Cirripedia larva	1
VII	MIT	Quadrat	Foraminifera	
			Decapoda	2
			Gastropoda	29
			Algae	present
VII	MIT	Van Veen	Nemertea	128
			Copepoda	41
			Nematoda	35
			Cirripedia larvae	5
			Pelecypoda	3
			Isopoda	1
			Polychaeta	66
			Decapoda larva	7
			Acarida	4
			Cladocera	1
			Eggs	present
VII	LIT	Quadrat	Foraminifera	4
			Isopoda	7
			Cirripedia larvae	4
			Holothuroidea	1
			Cirripedia juveniles	2
			Nematoda	18
			Copepoda	8
			Gastropoda	2
			Tanaidacea	2
			Pelecypoda	1
			Decapoda	1
			Polychaeta	23
			Ophiuroidea	1
			Algae	present
VII	LIT	Random	Nematoda	9
			Cirripedia larva	1
			Polychaeta	2
			Decapoda	17
			Copepoda	2



Traverse	Zone	Type Sample	Taxa	No.
VII	LIT	Van Veen	Turbellaria	254
			Ostracoda	99
			Nemertea	706
			Cirripedia	282
			Nematoda	6336
			Amphipoda	2
			Pelecypoda	10
			Cumacea	1
			Sipunculoidea	27
			Isopoda	10
			Oligochaeta	1
			Decapoda	10
			Polychaeta	2884
			Tanaidacea	143
			Acarida	10
			Echinoidea	2
			Copepoda	755
			Decapoda larvae	12
VIII	UIT	Van Veen	Nematoda	53
			Copepoda	82
			Gastropoda	45
			Ostracoda	15
			Pelecypoda	10
			Cirripedia	100
			Sipunculoidea	1
			Amphipoda	1
			Acarida	8
			Decapoda zoea	208
VIII	MIT	Random	Gastropoda	5
			Cirripedia	28
			Pelecypoda	1
			Decapoda	2
VIII	MIT	Van Veen	Foraminifera	present
			Copepoda	37
			Nematoda	683
			Ostracoda	2
			Gastropoda	1
			Cumacea	2
			Pelecypoda	2
			Cirripedia	81
			Polychaeta	33
			Decapoda zoea	46
			Acarida	1
			Algae	present



Traverse	Zone	Type Sample	Taxa	No.
VIII	MIT	Quadrat	Anthozoa	1
			Gastropoda	2
			Polyplacophora	2
			Decapoda	34
			Nematoda	18
			Cirripedia	29
			Pelecypoda	1
			Amphipoda	4
			Copepoda	13
VIII	LIT	Van Veen	Nematoda	3828
			Cirripedia	38
			Oligochaeta	17
			Cumacea juveniles	5
			Polychaeta	36
			Isopoda	4
			Acarida	1
			Decapoda larvae	138
			Copepoda	102
			Ostracoda	2
			Algae	present
VIII	LIT	Quadrat	Nematoda	148
			Cumacea	2
			Decapoda larvae	6
			Copepoda	31
			Cirripedia larvae	6
VIII	LIT	Random	Gastropoda	2
			Asteroidea	1
			Pelecypoda	1
			Decapoda	3
			Polychaeta	1
VIII	LIT	Random	Gastropoda	7
			Asteroidea	1
			Pelecypoda	1
			Decapoda	3
			Polychaeta	3
VIII	SST	Van Veen	Pelecypoda	13
			Polychaeta	37



Traverse	Zone	Type Sample	Taxa	No.
VIII	DST	Trawl	Polychaeta	1
			Decapoda	10
			Cirripedia	2
			Osteichthyes	3
			Asteroidea	1
IX	UIT	Random	Gastropoda	13
			Decapoda	2
IX	UIT	Quad: at	Gastropoda	22
			Xanthidae	17
			Pelecypoda	1
IX	UIT	Van Veen	Nematoda	11
			Ostracoda	4
			Gastropoda	3
			Cirripedia larvae	3
			Polychaeta	69
			Amphipoda	10
			Acarida	6
			Xanthidae	2
			Copepoda	11
IX	MIT	Random *	Cirripedia	81
IX	MIT	Quadrat	Gastropoda	14
			Osteichthyes	1
			Pelecypoda	8
			Decapoda	18
			Isopoda	3
			Copepoda	6
			Nematoda	2
			Cirripedia larvae	10
			Amphipoda	67
IX	MIT	Van Veen	Nematoda	22
			Ostracoda	20
			Gastropoda	21
			Cirripedia	55
			Pelecypoda	8
			Amphipoda	961
			Sipunculordea	32
			Isopoda	23
			Polychaeta	144
			Decapoda	13
			Acarida	4
			Decapoda larva	1
			Copepoda	182

* Bottle broken



Traverse	Zone	Type Sample	Taxa	No.
IX	LIT	Random	Turbellaria	2
			Cirripedia	1
			Nemertea	37
			Amphipoda	1
			Nematoda	14
			Gastropoda	4
			Decapoda	10
			Polychaeta	7
			Asteroidea adult	7
			Acarida	2
			Asteroidea juvenile	45
			Copepoda	33
			Osteichthyes	11
			Ostracoda	1
IX	LIT	Quadrat	Nematoda	207
			Copepoda	185
			Ostracoda	7
			Gastropoda	8
			Decapoda larvae	3
			Polychaeta	21
			Decapoda	9
			Amphipoda	10
			Portunidae	1
			Polyplucophora	4
			Pinnotheridae	1
			Gastropoda	8
			Cirripedia	6
			Pelecypoda	2
			Isopoda	2
			Oligochaeta	38
			Acarida	13
IX	LIT	Van Veen	Gastropoda	8
			Decapoda	4
			Polychaeta	6
			Portunidae	1
			Amphipoda	5
			Pinnotheridae	1
			Decapoda larvae	3



Traverse	Zone	Type Sample	Taxa	No.
IX	DST	Van Veen	Foraminifera	66
			Copepoda	14
			Nematoda	16
			Ostracoda	14
			Gastropoda	4
			Cirripedia larvae	4
			Polychaeta	8
			Amphipoda	10
X	UIT	Quadrat	Gastropoda	30
			Amphipoda	2
			Pelecypoda	6
			Decapoda	10
			Cirripedia	2
			Nematoda	6
			Polychaeta	1
			Polyplacophera	8
			Thaidacea	1
			Algae	present
X	UIT	Random	Gastropoda	10
			Amphipoda	2
			Pelecypoda	1
			Decapoda	3
			Cirripedia	1
			Cirripedia larva	1
X	UIT	Van Veen	Foraminifera	present
			Acarida	18
			Nematoda	37
			Copepoda	52
			Gastropoda	1
			Ostracoda	4
			Pelecypoda	6
			Amphipoda	87
			Polychaeta	215
			Algae	present
X	MIT	Van Veen	Foraminifera	present
			Copepoda	107
			Nemertea	4
			Ostracoda	43
			Nematoda	62
			Cirripedia	85
			Gastropoda	3
			Amphipoda	1



Traverse	Zone	Type Sample	Taxa	No.
X	MIT	Van Veen	Pelecypoda Eggs Polychaeta	6 present 165
X	MIT	Random	Gastropoda Cirripedia Pelecypoda Decapoda Polychaeta Copepoda Nematoda Cirripedia larvae	8 29 3 3 3 4 3 7
X	MIT	Quadrat	Gastropoda Decapoda Cirripedia Oligochaeta Nematoda Polychaeta Polyplacophora Copepoda Pelecypoda Cirripedia	23 4 3 3 9 8 9 2 1 3
X	LIT	Random	Turbellaria Cirripedia larvae Gastropoda Algae Cirripedia Copepoda Nematoda Ostracoda Pelecypoda Amphipoda Cumacea Oligochaeta Isopoda Polychaeta Acarida	1 91 6 present 51 267 88 15 6 2 1 3 1 11 3
X	LIT	Van Veen	Turbellaria Ostracoda Nematoda Cirripedia Pelecypoda Amphipoda	1 422 5698 55 113 34



Traverse	Zone	Type Sample	Taxa	No.
X	LIT	Van Veen	Oligochaeta	30
			Cumacea	136
			Polychaeta	378
			Isopoda	5
			Acarida	13
			Tanaidacea	18
			Copepoda	6700
			Decapoda larvae	3
X	LIT	Quadrat	Turbellaria	4
			Acarida	71
			Nematoda	1829
			Copepoda	4553
			Gastropoda	24
			Ostracoda	810
			Nudibranchia	1
			Cirripedia	25
			Pelecypoda	47
			Amphipoda	43
			Sipunculoidea	27
			Cumacea	58
			Polychaeta	175
			Isopoda	20
X	SST	Van Veen	Anthozoa	1
			Nematoda	514
			Polychaeta	6
			Copepoda	250
			Gastropoda	3
			Ostracoda	6
			Pelecypoda	1
			Amphipoda	182
			Oligochaeta	4
			Isopoda	1
			Decapoda	1
XI	UIT	Random	Nematoda	1
			Copepoda	1
			Gastropoda	15
			Cirripedia	6
			Pelecypoda	2
			Amphipoda	1
			Polychaeta	1
			Decapoda	3
			Acarida	1
			Polyplacophora	2



Traverse	Zone	Type Sample	Taxa	No.
XI	UIT	Quadrat	Gastropoda	6
			Decapoda	2
XI	UIT	Van Veen	Nematoda	25
			Amphipoda	5
			Gastropoda	4
			Isopoda	16
			Copepoda	4
XI	MIT	Random	Scyphozoa	1
			Cirripedia	12
			Turbellaria	16
			Cirripedia larva	1
			Nematoda	1
			Amphipoda	5
			Polyplacophora	1
			Isopoda	3
			Gastropoda	31
			Paguridae	60
			Pelecypoda	3
			Decapoda	2
			Copepoda	17
			Ostracoda	1
			Algae	present
XI	MIT	Quadrat	Gastropoda	6
			Cirripedia	4
			Pelecypoda	2
			Decapoda	20
			Nematoda	1
			Copepoda	4
			Cirripedia larvae	9
XI	MIT	Van Veen	Nematoda (estimate)	1500
			Cirripedia	5
			Gastropoda	1
			Amphipoda	63
			Pelecypoda	1
			Isopoda	120
			Polychaeta	3
			Decapoda	4
			Acarida	2
			Copepoda	8
			Algae	present



Traverse	Zone	Type Sample	Taxa	No.
XI	LIT	Quadrat	Nemertea	1
			Polychaeta	15
			Nematoda	5
			Amphipoda	3
			Gastropoda	6
			Echinoidea	1
			Pelecypoda	2
			Decapoda	9
XI	LIT	Random	Brachiopoda	1
			Amphipoda	1
			Polyplacophora	3
			Decapoda	3
			Gastropoda	5
			Asteroidea	2
			Cirripedia	4
			Osteichthyes	2
			Foranucra	5
			Decapoda zoea	1
XI	LIT	Van Veen	Foraminifera	
			Polychaeta	111
			Copepoda	286
			Nematoda	3522
			Amphipoda	23
			Gastropoda	1
			Decapoda	6
			Pelecypoda	4
			Cirripedia larvae	7
XI	DST	Van Veen	Nematoda	153
			Copepoda	165
			Gastropoda	11
			Ostracoda	20
			Nudibranchia	3
			Amphipoda	6
			Pelecypoda	4
			Cumacea	2
			Polychaeta	6
			Isopoda	15
			Acarida	1
			Decapoda	4



Traverse	Zone	Type Sample	Taxa	No.
XII	UIT	Van Veen	Nematoda	45
			Cirripedia	4
			Copepoda	3
XII	UIT	Random	Polyplacophora	9
			Cirripedia	6
			Pelecypoda	1
			Decapoda	1
XII	MIT	Van Veen	Foraminifera	
			Cirripedia	8
			Nematoda	4
			Isopoda	5
			Acarida	5
			Insecta	12
			Copepoda	13
			Algae	present
XII	MIT	Random	Gastropoda	4
			Cirripedia larvae	5
XII	MIT	Quadrat	Nematoda	1
			Amphipoda	2
			Polychaeta	1
			Cumacea	1
			Copepoda	1
XII	LIT	Quadrat	Foraminifera	3
			Ostracoda	3
			Nematoda	3
			Amphipoda	23
			Gastropoda	10
			Polychaeta	4
			Algae	present
XII	LIT	Random	Gastropoda	2
			Polychaeta	2
			Decapoda	1
XII	SST	Van Veen	Nematoda	17
			Ostracoda	6
			Gastropoda	6
			Cirripedia	3
			Polychaeta	107
			Amphipoda	7
			Copepoda	192
			Caprellidae	4



Traverse	Zone	Type Sample	Taxa	No.
XII	DST	Van Veen	Nematoda	3
			Gastropoda	1
			Polychaeta	5
			Copepoda	48
XIII	UIT	Quadrat	Polyplacophora	1
			Pelecypoda	3
			Gastropoda	8
			Amphipoda	26
			Nematoda	2
			Copepoda	4
			Ostracoda	1
			Cirripedia	2
XIII	UIT	Van Veen	Turbellaria	33
			Acarida	59
			Nemertea	3
			Copepoda	17
			Nematoda	10
			Ostracoda	2
			Gastropoda	3
			Cirripedia larvae	13
			Polychaeta	45
			Amphipoda	2
XIV	SST	Trawl	Nemertea	1
			Amphipoda	104
			Nematoda	169
			Caprellidae	4
			Gastropoda	1
			Isopoda	23
			Nudibranchia	1
			Decapoda	36
			Sipunculoidea	220
			Asteroidea	2
			Polychaeta	22
			Osteichthyes	6
			Ostracoda	29
			Cirripedia	1
			Cirripedia larvae	5
			Algae	present
			Crab egg masses	present



Traverse	Zone	Type Sample	Taxa	No.
XIV	SST	Van Veen	Nematoda	2138
			Pelecypoda	1
			Polychaeta	84
			Copepoda	1938
			Ostracoda	11
			Cirripedia larvae	5
			Amphipoda	20
			Cumacea	12
			Isopoda	22
			Tanaidacea	11
			Decapoda	1
XV	SST	Trawl	Isopoda	1
			Osteichthyes	11
			Decapoda	2
XV	SST	Van Veen	Nemertea	53
			Nematoda	1796
			Nudibranchia	1
			Sipunculoidea	1
			Polychaeta	34
			Acarida	1
			Copepoda	715
			Ostracoda	127
			Cirripedia	4
			Cumacea	1066
			Isopoda	3
			Decapoda larvae	4
			Amphipoda	365
			Tanaidacea	76
XVI	SST	Trawl	Porifera	2
			Nematoda	184
			Amphipoda	170
			Gastropoda	20
			Caprellidae	5
			Nudibranchia	3
			Cumacea	3
			Pelecypoda	3
			Isopoda	22
			Sipunculoidea	1
			Decapoda	81
			Polychaeta	138
			Decapoda larvae	74
			Acarida	44



Traverse	Zone	Type Sample	Taxa	No.
XVI	SST	Trawl	Tanaidacea	21
			Copepoda	679
			Asteroidea	1
			Ostracoda	1177
			Osteichthyes	22
			Cirripedia	1
			Algae	present
XVI	SST	Van Veen	Turbellaria	4
			Nematoda	2243
			Gastropoda	1
			Pelecypoda	1
			Polychaeta	97
			Acarida	23
			Pycnogonida	1
			Copepoda	2011
			Ostracoda	309
			Cirripedia larva	1
			Amphipoda	55
			Caprellidae	4
			Cumacea	8
			Isopoda	1
			Decapoda	2
			Tanaidacea	428
XVII	UIT	Random	Cirripedia	3
			Isopoda	1
			Amphipoda	6
XVII	UIT	Van Veen	Foraminifera	
			Polychaeta	2
			Nematoda	19
			Copepoda	2
XVII	MIT	Van Veen	Nemertea	3
			Copepoda	7
			Nematoda	58
			Cirripedia	8
			Gastropoda	1
			Amphipoda	1
XVII	MIT	Quadrat	Nemertea	1
			Polychaeta	1
			Nematoda	1
			Decapoda	1
			Gastropoda	1
			Algae	present



Traverse	Zone	Type Sample	Taxa	No.
XVII	MIT	Random	Nematoda	7
			Gastropoda	10
			Cirripedia	7
			Pelecypoda	8
			Decapoda	1
			Acarida	1
			Copepoda	3
			Trematoda	1
			Cirripedia larvae	55
XVII	LIT	Random	Decapoda	3
			Osteichthyes	3
			Cirripedia larvae	2
			Nematoda	35
			Amphipoda	1
			Polychaeta	3
			Isopoda	1
XVII	LIT	Quadrat	Copepoda	2
			Nematoda	223
			Gastropoda	13
			Polychaeta	5
			Copepoda	68
			Ostracoda	324
			Cirripedia	2
			Amphipoda	15
			Cumacea	4
XVIII	UIT	Van Veen	Isopoda	2
			Foraminifera	
			Polychaeta	36
			Nemertea	9
			Copepoda	28
			Nematoda	50
			Tanaidacea	1
XVIII	UIT	Random	Acarida	1
			Decapoda	1
XVIII	UIT	Quadrat	Tanaidacea	6
			Copepoda	1
XVIII	MIT	Van Veen	Foraminifera	
			Nemertea	13
			Cirripedia larvae	118
			Nematoda	281
			Amphipoda	2
			Gastropoda	9



Traverse	Zone	Type Sample	Taxa	No.
XVIII	MIT	Van Veen	Sipunculoidea	1
			Tanaidacea	2
			Polychaeta	179
			Copepoda	125
			Algae	present
XVIII	MIT	Quadrat	Turbellaria	10
			Nemertea	17
			Nematoda	192
			Gastropoda	2
			Polychaeta	51
			Copepoda	210
			Ostracoda	7
			Cirripedia	46
			Amphipoda	3
			Isopoda	4
			Decapoda larvae	4
XVIII	MIT	Random	Nematoda	2
			Sipunculoidea	1
			Polychaeta	8
			Copepoda	5
			Cirripedia	14
			Cirripedia larvae	10
			Isopoda	4
XVIII	LIT	Random	Nematoda	63
			Polychaeta	2
			Ostracoda	1
			Osteichthyes	1
			Copepoda	22
XVIII	LIT	Van Veen	Turbellaria	33
			Nemertea	7
			Nematoda	4557
			Gastropoda	1
			Pelecypoda	3
			Polychaeta	251
			Copepoda	3758
			Ostracoda	70
			Cirripedia larvae	125
			Amphipoda	63
			Cumacea	71
			Isopoda	2
			Tanaidacea	4



Traverse	Zone	Type Sample	Taxa	No.
XVIII	LIT	Quadrat	Turbellaria	44
			Nematoda	1185
			Gastropoda	37
			Pelecypoda	2
			Polychaeta	789
			Acarida	8
			Copepoda	4247
			Ostracoda	44
			Cirripedia larvae	103
			Amphipoda	85
			Cumacea	17
			Isopoda	7
			Decapoda larvae	4
XVIII	DST	Van Veen	Nematoda	37,832
			Polychaeta	184
			Copepoda	1732
			Ostracoda	32
			Amphipoda	25
			Cirripedia larvae	8
			Tanaidacea	8